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DRY ROT AND THE DEATH-WATCH BEETLE

IN WHICH THE ORIGIN AND LIFE HISTORY
OF THE TWO WORST ENEMIES OF TIMBER
ARE GIVEN, WITH A DESCRIPTION OF THE
DAMAGE THEY CAUSE, AND THE METHODS TO
BE ADOPTED FOR THEIR EXTERMINATION

BY

ERNEST G. BLAKE, M.R.S.I.
Medallist in Sanitary Building Construction
AUTHOR OF "DAMP WALLS," "PLUMBING," "THE SEASONING AND
PRESERVATION OF TIMBER," "ROOF COVERINGS," ETC., ETC.

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PREFACE

WHEN the tremendous quantity of timber that is used every year is compared with the length of time that is occupied by the tree in reaching full maturity, it would almost appear at first sight as if the whole world would be denuded of its forest trees in a very short space of time, and that, failing some means of increasing the supply or of providing an efficient substitute, the wheels of commerce and industry would inevitably come to a dead stop before many years have passed for the want of raw material on which to work. And this impression, serious as it may be, cannot altogether be dismissed as a figment of the imagination, when it is considered that the shortest space of time in which most trees will attain to dimensions when they can be dignified by the name of " timber " is not less than fifty years, and in some species more than twice as long. Add to the quantity that is normally used in industry the excessive amount that is wasted in one way or another every year, and the contingency is at once brought appreciably nearer. It is decidedly fortunate, from this point of view, that the bulk of the timber that is used for industrial purposes is of the soft-wooded coniferous varieties, as these trees attain maturity in a very much shorter space of time than the hardwoods, and therefore can be replaced much more rapidly.

In the large timber-producing regions of the earth, from which we in this country satisfy the bulk of our requirements, such as the American continents, Scandinavia, Russia, and the north of Europe generally, vast tracts of forest land have always been available in the past from which unlimited supplies could be obtained, and these tracts have been exploited in the most ruthless and wasteful manner. This practice has now to some extent ceased, as it is realised that such methods cannot go on for ever, and grave fears have been entertained that the end of the world's available supply of timber is within measurable distance. Various substitutes for timber have been brought into use during the last quarter of a century, and, in the building industry especially, new methods of construction have been devised whereby the employment of timber has been very largely reduced. Fresh methods and processes, however, are continually being introduced in various directions in which wood of some kind or other is an essential feature, so that what is gained on one side is more or less counterbalanced by a corresponding loss on the other.

There is probably no country in the world which is not guilty of a certain amount of avoidable waste, owing either to decay or to the damage that is wrought by insects and vermin. Wet rot is doubtless the greatest offender in this part of the world, where the variable climatic conditions are practically sure to cause a good deal of decomposition in the absence of preventive measures. A great deal of this decay could be prevented by the introduction of an organised system for preserving the timber before it is used, but it is not proposed to deal with this aspect of the question at the present moment. The two factors which influence the durability of timber that it is proposed to consider are the effects of dry rot and the ravages of the death-watch beetle or wood-worm, the former of which results in a chemical change in the composition of the timber, while in the latter the damage is of a purely mechanical nature.

While both dry rot and the wood-worm are responsible for the destruction of a large quantity of timber every year—and it should be noted that the loss is cumulative, as in both cases the particular disease can be communicated by infected wood to newer and uninfected timber in the vicinity after, or even before, its own destruction is complete—there is another, and not less important, aspect which must be considered, *i.e.* the danger that arises of the possible collapse of any structure that is badly affected and the risk to life and limb should such a collapse occur without warning. Thus a far more serious factor than mere waste enters into the question, and the utmost care and circumspection should be exercised in providing adequate protection against such a danger, and in seeing that remedial measures are put into operation without delay in cases where disease already exists. Dry rot is a disease which is caused by the action of a vegetable parasite, operating under suitable conditions, while the ravages of the death-watch beetle can surely be classed in the same category for present purposes, owing to the marked similarity in its methods of attack and in the ultimate condition to which the timber is reduced by the operations of the insect.

So much interest was aroused by the very brief chapter on the origin and cure of dry rot that was included in " The Seasoning and Preservation of Timber," and the volume was accorded such a gratifying reception on all hands, especially this particular section, that it has been thought that a more detailed description of the disease, and of the safest methods that can be adopted in such cases, would be welcomed by many who are interested in the subject. In addition to this, a tremendous amount of interest has lately been exhibited in the facts that have recently come to light with regard to the operations of the death-watch beetle, and much anxiety has been engendered by the dangerous state in which the roofs and timber work of many of our national buildings have been found. A description of the beetle, with details of the methods by which it produces such amazing results, has therefore been included in this volume, in the hope that the information may be of some little interest, not only to those whose daily avocations are concerned with the maintenance of buildings of any kind, but also to that wider circle of the public which may desire to become acquainted with the latest discoveries and information on what has so far been a comparatively little-known subject.

Before commencing on the subject-matter of the book I must express my sincere thanks and acknowledgments to Dr. H. Maxwell-Lefroy, M.A., Professor of Entomology at the Imperial College of Science and Technology, London, who has kindly been to some little trouble in providing me with the very latest information as to the methods that have been found most effective in dealing with the death-watch beetle, and also in supplying some very interesting photos of the beetle and its grub. I also desire to thank Dr. C. J. Gahan, D.Sc., of the Department of Entomology, South Kensington, for many of the particulars that are given respecting the life history of the beetle, from which some of the illustrations have been drawn; and the Society of Antiquaries of London for permission to quote briefly from one of their leaflets on the subject, and to reproduce those illustrations which indicate the actual size and appearance of the exit holes that are made by the beetles.

It is hoped that the perusal of the following pages will impart as much useful information and pleasure to the reader as the compilation of the volume has given to me during the last few months; its production will then be fully justified, and the object that is aimed at in all works of this description will undoubtedly be achieved, to the benefit of all concerned.

E. G. B.

Windsor, 1925.

CONTENTS

PART I

DRY ROT

CHAPTER I

PAGE

TIMBER: ITS NATURE AND LIABILITY TO DECAY . . 3

Waste—The *Teredo navalis*—White ants—Dry rot—Exogens—Endogens—Broad-leaved trees—Needle-leaved trees—Hardwoods—Softwoods—The growth of a tree—Section of pine tree—Pith—Medullary sheath—Annual rings—Cambium—Medullary rays—Spring-formed wood—Autumn-formed wood—Sap—Age at maturity—Organic matter in wood—Painting and creosoting—Durability—Cellulose—Lignin—Composition of wood and cellulose compared—Wet rot—Decay—Wood a million years old—The death-watch beetle—Soil bacteria—" Eremacausis "—Fungi.

CHAPTER II

DRY ROT: ITS PROPAGATION AND DEVELOPMENT . . 25

The result of neglect—The nature of dry rot—Wet rot—*Merulius lachrymans*—*Coniophora cerebella*—*Polyporus vaporarius*—The germination of the spore—Spores—The spread of dry rot—Conditions favourable to dry rot—Destruction by heat—Effect of cold—Moisture requirements—Its erratic nature—Dry rot in North Wales—The growth of the spore—Hyphæ—How they attack timber—Mycelium—The fructification of the mycelium—Range of the hyphæ—*Merulius lachrymans* manufactures water—Origin of its name—Distinguishing characteristics—Indications of dry rot—Tests for dry rot—The results of dry rot—Reduction in strength of timber—Destruction of a floor in nine months—Danger of dry rot in stables—Roots of ivy mistaken for dry rot—Colour of hyphæ.

CHAPTER III

PAGE
THE PREVENTION OF DRY ROT IN NEW BUILDINGS . 48

Prevention better than cure—Conditions to be guarded against—Dampness—Stagnant atmosphere—Warmth—Darkness—Unseasoned or infected wood—Predisposing cause of dry rot—Fresh air—Ventilation—Currents of air—Air-bricks—Partition walls—The theory of ventilation—Density and equilibrium of air—Expansion of heated air—Circulation of air—Where to insert air-bricks—The production of cross currents—Honeycombed walls—Displacement of air by heat—Improved method of inserting air-bricks—Dampness of site—Concreted site—Condensation—Atmospheric moisture—Saturated air—Rain—Dew—" Dew point "—Water-logged districts—Remedy for dampness—Air-shaft for ventilating—Mica flap ventilator—Ventilating upper floors—Air pocket round ends of beam—Iron plates and bond timbers—Wood block floors—Floor boards nailed to concrete—Lime pugging—Silicate cotton—Cabot's Quilt—Linoleum—Vitality of hyphæ—Preservative treatment—The Powell Wood-Process system—Sapwood—Risk of infection of timber—Infected timber yards—Importance of using dry timber.

CHAPTER IV

THE ERADICATION OF DRY ROT FROM OLD BUILDINGS . 81

Difficulties that are met—Old property—Signs of dry rot—Dry rot in a Yorkshire house—Inspection of floors—Object to be aimed at—Removal of infected timber—Cleansing the walls and floor—Disinfecting—Bichloride of mercury—Carbolic—Spraying—Burning—Concreting the site—Rendering with waterproofed cement mortar—Rendering the walls—Inserting air-bricks—Air-shaft—The replacement of bond timbers and plates with iron—Air pockets round ends of beam—Stone corbels for support of beam—Selection of new timber—Disinfection of tools—Reinstatement of floor and skirtings—Sleepers laid dry—Honeycombing sleeper walls—Fixing skirting and panelling—Ventilating beneath solid floors—" Tobin's " tube—Porous concrete—Rendering old concrete—Asphalte

PAGE

as a covering—Coal tar and pitch—Broken eaves gutters—Flooded cellar in the north of England—Air drain—Vertical damp-proof course—" Damp walls."

PART II

THE DEATH-WATCH BEETLE

CHAPTER V

THE COMMON FURNITURE BEETLE 107

Liability of timber to attack—Wood-boring insects—White ants—Destruction that is caused—The common furniture beetle—The death-watch beetle—Similarity of attack — Worm-eaten furniture — Mr. William Stevenson on the beetle—*Anobium punctatum*, the furniture beetle—Its eggs—Description of the beetle—Its habits—Pairing—The eggs laid—The larva—Its operations—Method of boring—Digestion of the wood—The pupation stage approaches—Preparations for changing—The pupa or chrysalis—The complete beetle—Time of the life-cycle—Dr. Gahan on the beetle—Exit holes—Remedies—Paraffin—Its application—Vinegar—Benzene — Petrol — Turpentine — Naphthalene — Carbon tetrachloride — Bichloride of mercury — Methyl alcohol—The *Deutsche Tischler Zeitung*—Soap lye—Carbolineum—Calcium or lime sulphate—Heat — Fumigation with gas or vapour — Temperature required—Fumigating apparatus—Hydrocyanic acid gas—Carbon disulphide—Sulphur dioxide—Brimstone — Benzene — Carbon tetrachloride — Ammonia — Report to Science and Art Department—Destroying the larvæ at South Kensington Museum—Mercuric chloride—Parchment lye—Creosote.

CHAPTER VI

THE DEATH-WATCH BEETLE 135

Danger that is caused—*Xestobium tessellatum*, the death-watch beetle—Its life-cycle—The sex call—Why it is made—How it is made—Superstition attached to the sex call—Pairing time—Depositing the eggs—Incubation—The larva or grub—Its spines—How it pushes

PAGE

its way along—The jaws of the larva—Enlarged head of larva—Description of larva—The grub in its burrow—Sapwood and heartwood equally affected—Adjacent timbers attacked—The beetle in St. George's Chapel—Helplessness of the larva—Yeast in the digestive organs—Fermentation of the wood particles—Professor Maxwell-Lefroy on the beetle—Damage caused by a single grub—Pupation—The beetles emerge—Size and appearance of beetle—Origin of an attack—The use of infested timber—The beetle flies in—The cessation of an attack—Conditions in which the beetle thrives.

CHAPTER VII

WESTMINSTER HALL 154

An unique national possession—Skilful workmanship—The old time craftsman—Age of the Hall—Commenced by William Rufus—Replacement of the roof in 1394 by Richard II.—Its designer—Tribute of Sir Frank Baines—Coronation banquets—Trial of Bishop Fisher—Impeachment of Laud and the Earl of Strafford—Trials of Charles I., Byron, Lord George Gordon, and the seven bishops—Impeachment of Warren Hastings—Lying in state of King Edward VII.—Repairs to the roof at various times—Extract from the *Observer* in 1821—Indications of trouble in 1913—Government Blue Book in 1914—Report by Mr. Frank Baines—Description of damage—The death-watch beetle—Test of its boring power—Dimensions of beams—Suggestions for repairing the roof—Extreme danger of collapse—Steel reinforcement—Completion of the work in 1923—Reopening of the Hall by the King—His Majesty's speech—Statement by Sir John Baird—Extent of repairs.

CHAPTER VIII

THE DESTRUCTION OF THE BEETLE 171

Difficulties ahead—The problem to be solved—Test for worm-eaten wood—Watchfulness needed—Neglect and its consequences—The problem solved by Professor Maxwell-Lefroy—Caution in using new wood for repairs—Disinfection of the timber—Timber *in situ*—A little-known subject—Later discoveries—Treatment of infested timber—Heat—Fumigation—Impregnation—Treatment must be thorough—Points to consider in treatment by a liquid—The first solution employed—An alternative solution—Spraying the roof—A third solution—Bichloride of mercury—Objection to poisonous materials—The latest solution—Much simpler and safer—How it operates—Cost of treatment—The condition of Peterborough Cathedral—Public appeal—Funds required—Cost of repairs to Westminster Hall roof—Society of Antiquaries leaflet—Where to look for danger—To diagnose an attack—Treating the timber with a liquid—Forcing the solution in—A liquid to strengthen the beam—Ventilation—Illumination—The Curfew Tower at Windsor Castle—Church towers and belfries—Warmth—Its influence on the larvæ—How to spray—Spraying apparatus used at Westminster—How the roof was sprayed—Date of attack—Need for scientific research—His Majesty's Office of Works and Ancient Monuments.

LIST OF ILLUSTRATIONS

PART I

FIG. PAGE
1. Cross Section of Pine Tree 11
2. Mycelium of Dry Rot 37
3. Fructification of the Mycelium of Dry Rot *Facing* 38
4. Timber badly attacked by Dry Rot . . . 41
5. Improved Method of inserting Air-brick . . 60
6. Plan of Building showing Method of Ventilation and Exclusion of Damp. 61
7. Air-shaft for Ventilation 67
8. Air Pocket round End of Beam . . . 70
9. Iron Bar in place of Wood Plate . . . 71
10. Timber Destroyed by Dry Rot . . *Facing* 80
11. Method of Ventilation beneath Solid Floor . 99
12. Method of Ventilation with Air Pit . . 100

PART II

13. The Common Furniture Beetle . . *Facing* 115
14. Exit Holes made by the Common Furniture Beetle . . . . . . *Facing* 119
15. Larva of the Death-watch Beetle . . . 140
16. Enlarged Head of Death-watch Beetle . . 141
17. Larva of Death-watch Beetle in its Burrow *Facing* 142
18. End of Badly Eaten Oak Beam . ,, 142
19. The Death-watch Beetle . . . ,, 146
20. Side View of the Death-watch Beetle ,, 146
21. Westminster Hall Roof . . . ,, 170
22. Exit Holes made by the Death-watch Beetle *Facing* 186

PART I

DRY ROT

CHAPTER I

TIMBER : ITS NATURE AND LIABILITY TO DECAY

THE discovery of methods whereby the prevention of waste can be avoided offers a very wide field for the economist in the course of his endeavours to improve the lot of mankind from a material point of view. It is obvious that waste of any kind must necessarily mean that there will be less of the article in question to be distributed amongst those who perhaps most require it, and whose well-being demands that a more or less plentiful supply shall be available to satisfy their general needs. Hence the continued waste of a commodity, on a scale of any magnitude, cannot but assist in the creation of a shortage of that commodity in time, and the results may quite conceivably be deplorable from a national point of view.

At the present day a very great deal of unnecessary extravagance is indulged in which might, with a little thought, be at least curtailed in the public interest. This prodigality is not confined by any means to one class of society, neither does it apply to any one kind of material. We know that a tremendous quantity of really nourishing food is often thoughtlessly cast away, while numbers of the population are in daily need of the bare necessaries of life, this constituting positive waste. On the other hand, many of the by-products, or so-called refuse, from various manufacturing processes are still treated as useless, and disposed of in the easiest manner that can be found without any real investigation into their potentialities. This may be described as negative waste. Perhaps, as time goes on, some method may be found whereby all these superfluous materials can be usefully employed, so that not only will the national wealth be increased, but the amenities of both town and country districts will not be destroyed by the sight of huge mounds of waste material, that cannot be disposed of in any other way than by letting it lie and rot. During the late war large quantities of odds and ends of material were utilised for various purposes, and it seemed as if the potential wealth that reposes in old tins, paper, and such like, would not be lost sight of again ; but with the cessation of hostilities these thrifty methods were gradually allowed to die out, and now we appear to be adopting practically the same system as existed before the war.

Now, as it has already been indicated, there are two distinct kinds of waste, *i.e.* deliberate and unavoidable. The former may be, and in fact is, extremely reprehensible, as some one is bound to suffer from its effects, but we are not concerned with this at the moment. What is generally considered to be unavoidable waste, however, can often be controlled to some extent, and it can generally be limited to a much greater extent than it is now. Practically all materials that are in use at the present day, whether organic or inorganic, are subject to wastage in some form or other, either by decomposition, attrition, or breakage from careless usage, and all of these may arise from the unsuitability of the material for the purpose for which it is used. This can be avoided to some extent, either by providing suitable protection against the cause of the wastage, by more careful handling, or by a more intelligent consideration of the material and the uses to which it is put.

There is, perhaps, no material which suffers so much from decomposition, owing to its use under unsuitable conditions, as timber, and the percentage of waste from this cause is very high. Timber, being an organic substance, is peculiarly liable to decomposition when it is exposed to the effects of the elements, and if it is employed in an exposed situation without some protection from rain and sun, it rapidly decays. Now, decomposition is a very gradual process, which goes on unseen and unheard, and a great deal of damage may be done before the results become apparent; hence, to prevent its occurrence, some steps should be taken to discount the inevitable effects before they have the opportunity to materialise. The quantity of timber that is wasted every year throughout the world from various causes is tremendous, and a good deal of concern has lately been felt at the results of the short-sighted methods that have been adopted in the past. These methods have, no doubt, been caused very largely by the possession of the immense areas of forest land that have been gradually maturing in many parts of the world, as the supply has been so plentiful that it has usually paid better at the moment to utilise only the best portions of the timber and to destroy the remainder, this being largely owing to the difficulty and the cost of transport. In addition to this, tremendous havoc has been caused by forest fires, when millions of cubic feet of valuable timber have been destroyed, without the slightest material advantage being gained to balance its loss. And all this deplorable waste has been caused chiefly through ignorance, or by actual neglect. Better counsels seem to be prevailing at the present time, however, and steps are now being taken to conserve what is left of this indispensable commodity, and to use it in the most advantageous manner, although it appears to be rather late in the day to think about reducing the losses after so much unnecessary extravagance has been going on for so long a time. Still, the new movement is all to the good, and if successful, it should operate for the benefit of all timber-consuming countries.

There is little doubt that the chief cause of the wastage of converted timber is decay arising from the action of the elements. A great deal of timber has been used in the past for rough work, such as in fences, outbuildings, etc., in situations where it is continually exposed to the weather, and little or nothing has been done towards protecting it against decay. Tarring and such-like measures have certainly been resorted to, but the treatment has often been carried out in a more or less perfunctory sort of manner, so that its effects are not nearly so far-reaching as would have been the case if a little more care and intelligence had been employed in carrying out the operation. More attention has also been paid to this side of the question of late years, and it is quite certain that the immense benefits that are derived from a really effective preservative treatment will be experienced as the years go by.

Much timber is also destroyed by the attacks of various insects, the damage in this case being of a mechanical nature, and quite distinct from the waste that is due to decomposition ; it is not, however, any less serious on that account. The white ant plays havoc with most kinds of timber in tropical countries, and especially with railway sleepers in India, and the question of how best to protect the wood-frame houses, sleepers, and other timber structures against their ravages has become so acute, that in many cases steel has been employed in the place of wood as the most effective means of countering their undesired attentions.

Then again, timber that is immersed in sea water is often seriously damaged by the *Teredo navalis*, or *ship worm*, a bivalved mollusc which bores into the fibres and tunnels through the interior with disastrous results. The ship worm is not so numerous as the white ant, but being very much larger—sometimes reaching to several feet in length—the damage is probably quite as serious, and being under water, it is less likely to be observed. There are many other species of wood-boring insects which cause a good deal of trouble at times to the standing tree. Most of these merely spoil the tree for timber purposes, however, without actually reducing its strength or cohesion to any great extent, so that the sum of their depredations is relatively small compared with the total consumption of timber throughout the year. One very important exception to this is the death-watch beetle, a full description of which will be given later on.

The subject which it is proposed to discuss in the first section of this volume, while being somewhat similar to the foregoing examples, at any rate so far as its ultimate results are concerned, is quite distinct from mechanical injury, not only in the causes that are responsible for its introduction and development, but also in the method of attack, and the complete and utter destruction which is the inevitable outcome of its activities. While it must be recognised that dry rot cannot be classed as decomposition in the ordinary sense of the word, as it is entirely dependent on the attack of a parasite, neither can it be included in the category of the mechanical destruction that is wrought by insects, although it combines somewhat of the nature of both. In one respect, however, the disease exhibits similar characteristics as are found in most of the attacks to which timber is liable, and under which it suffers so frequently. This is in the insidious nature of the development and progress of the disease, which may be propagated and continue to thrive for some considerable time without producing any very marked indications of its presence in the condition of the timber itself. This is a most vital aspect of the disease, which must not be overlooked, and which calls for the most frequent and searching examination of the timbers whenever any possibility of its presence exists. Before inquiring into the cause and effects of dry rot, however, it will be well to take a brief glance at the tree itself, and to examine its structure and composition, in order that a clear idea may be gathered of the method by which the disease is enabled to obtain a secure hold on the timber.

Trees are divided into two classes, called respectively " exogens " and " endogens." In the former class the layer of new wood that is added to the tree each year as it grows is formed on the outside of the trunk, immediately beneath the bark. These are the exogens, or outward growers, and it is from this class that all timber that is used for structural purposes is obtained. The endogens are described as inward growers, because the new tissue is formed annually at the centre of the tree instead of at the outside. In this case the line of division between the wood and the bark is very indistinct, as the connection between the two is not disturbed by the growth of fresh tissue each year. The various species of cane are included in this class.

The exogens, which constitute the source from which all timber that is used for commercial purposes is drawn, are also subdivided into two separate classes, which are known as the broad-leaved and the needle-leaved trees. The distinguishing characteristics of the two lie in the shape and formation of the leaves, these being in one case broad and flat and in the other long and narrow. The broad-leaved trees furnish the group of timbers known as the hardwoods, and include the oak, ash, beech, walnut, and elm, all of which are grown in these islands, and in addition mahogany, teak, jarrah, and various other species, which are only obtained from other parts of the world. The needle-leaved trees constitute the softwoods of commerce, and embrace the whole of the coniferous group, including the pines and firs, which are imported in immense quantities from America, Scandinavia, and Russia. Both the hardwoods and the softwoods possess distinct features of their own, all of which are characteristic of the particular class to which they belong. In the hardwoods the annual rings are nearly always narrow and well defined ; the colour of the wood is dark ; it has a close texture, and a comparatively high specific gravity ; and the sap has an acrid or aromatic taste. The softwoods differ from this in nearly every respect, as the annual rings are a good deal wider than in the previous class, and they are less distinct ; the wood is much lighter in colour ; the texture is not so close, and the grain is inclined to be woolly in many cases ; and the sap is of a resinous nature. In both cases, however, the normal growth of the tree follows on exactly the same lines, one layer of tissue being added each year beneath the bark. Each annual concentric ring consists of a light and a dark portion, the former being deposited in the spring and the latter in the autumn months, as will be seen in due course.

The annual growth of a timber tree commences in the spring, when the warm weather sets in after the low temperatures of the winter months, the influence of the sun forcing the roots into activity, so that they absorb water from the soil and pump it upwards through the complicated system of tubes into the tree. In the initial stages of the life of the tree nourishment is provided by way of the pith, which consists of a mass of loose cellular tissue ; as the tree expands, and its diameter increases, the sap is conducted through the harder fibre that is added year by year, and the function of the pith now being fulfilled, it gradually becomes exhausted and dies. The annual rings are composed of cellular tissue, made up of large numbers of very minute cells, which lie closely together and form the channel by which the nourishment that is extracted from the earth by the roots is passed on to the branches and ultimately assists in the formation of the leaves.

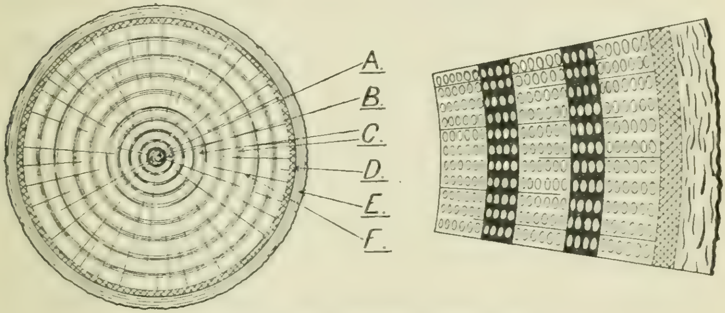

FIG. 1.—Cross Section of Pine Tree.

A cross-section of a portion of a timber tree is shown in Fig. 1. In the centre is the pith (A), which passes in a continuous line from the top to the bottom of the trunk, reaching out into the branches and the tiniest twigs. The pith, being of a soft and tender nature and unable to withstand the hard knocks of everyday life, is surrounded by a protective covering of harder tissue, called the medullary sheath (B), which completely envelops it, and divides it from the harder and more compact fibre that is deposited around it as time goes on, and which forms the annual rings or true wood (C). The number of these rings varies with the age of the tree, and the period of time that has been occupied in its growth can be estimated by allowing one year for each ring. At the outside of the true wood lies the cambium (D), which is immature tissue, and constitutes the wood in the process of formation ; this lies just beneath the bark (E). There are also numbers of fine lines (F), which radiate in all directions from the pith to the bark. These are the medullary rays, consisting of hard, flat sheets of wood, which are situated across the annual rings, between the fibres. Their function will be described presently.

The annual rings are gradually built up by the action of the sap as follows : In the early part of the year the roots spring into activity and commence to absorb the mineral salts and moisture from the soil ; the moisture is then forced up through the stem of the tree until it circulates through the branches. Here it passes into the leaves, and certain chemical changes take place which assist their development ; the moisture is then partially evaporated from the surface of the leaves. During its passage upwards from the soil the lighter and softer portion of the annual ring is formed between the bark and the previous year's growth. As the summer advances the leaves absorb carbonic acid (CO_2) from the atmosphere, and this assists the changes to take place in the sap until the autumn, when the sap returns to the roots again, forming the dark and harder portion of the annual ring as it descends. The texture of the autumn-formed wood is also made considerably closer and harder by the pressure of the bark, which has not been increasing at the same rate as the wood during the summer ; the formation of the autumn wood, however, increases the diameter of the tree so much, and sets up such a strain, that the bark cracks, thus relieving the pressure and providing room for the process to be repeated when the sap rises in the following spring.

As the development of the tree proceeds the wood at the centre becomes harder and darker in colour, as the sap only flows through the outside portion of the tree. This inner portion is called the heart, or " duramen " ; it is mature wood, and is the most durable part of the timber. The outside rings are of a lighter colour, owing to the presence of the sap ; it is generally a pale yellow in the softwoods and a brownish yellow in the hardwoods, and constitutes the " alburnum," or sapwood. The alburnum is much softer than the duramen, and as it soon decays, owing to the fermentation of the juices, it should not be used for structural purposes of any importance. When the downward flow of the sap has been completed in the autumn, the tree remains dormant until the return of warm weather ; this causes the roots to spring into activity again, and the whole process is repeated year by year, a new ring being formed each time.

The medullary rays shown at F in the illustration radiate from the centre towards the bark, while similar rays commence at the bark and reach part of the way inwards to the pith. The rays do not, as a rule, extend the whole distance from the centre to the circumference of the tree, and in addition they are comparatively short and do not reach from end to end of the trunk. Their function is to convey sap from the outside of the tree to the inner rings during the autumn descent, where it is distributed only to those portions where it is most needed. The sap is in a thickened form, and is absorbed by the cells at the centre, assisting to harden them and to render the timber more durable. In softwoods the medullary rays are very indistinct, and are practically invisible in the ordinary deal of commerce ; in the hardwoods, however, they are strongly marked, especially in oak, as they are of a very much lighter colour and closer texture than the surrounding tissue. In the evergreen oak, the rays are perhaps more distinct than in any other variety of tree, and very much harder ; evergreen oak, however, is not often used as a timber for structural purposes. When the log is quartered, or sawn in such a way that the cut passes obliquely through the medullary ray, it produces the beautiful silvery figure known as the " flower " in oak, but this method of cutting is very wasteful, and is only used for wainscoting, doors, furniture, and similar expensive work. When the living tree has passed maturity and decomposition sets in, the decay always commences at the pith and spreads outwards into the heartwood ; in converted timber, however, the sapwood is the first to decay, and it becomes completely rotten before the centre portion is very much affected.

The bark is separated from the true wood by the cambium, which is cellular tissue in the course of formation by the sap. It is the presence of the cambium which makes it possible for the bark to be stripped off the tree without difficulty in the spring, just before the buds burst into leaf. The stripping season for oak lasts about three or four weeks, and the operation is carried out after the tree has been thrown, the bark being removed in large sheets, and afterwards chopped into small pieces for use in the tanning industry. Oak for tanning has now been largely superseded by chemicals, and its value has decreased considerably.

Hardwoods are very slow-growing trees compared with the softer varieties, and consequently they take a much longer time to reach their full size. The reason for this is because the annual ring that is deposited is narrower in the former than in the latter, and as the cells are more compactly placed, the texture of the wood is denser and therefore harder. It is mainly on account of the slowness of growth that hardwoods are the more expensive of the two, as the extra cost of growing the tree to maturity and the increased durability which follows as a natural consequence, raise its commercial value to a considerable extent. The period that is required for elm to reach maturity in this country is about seventy years, oak requires from 100 to 150 years, while the coniferous varieties take from sixty years and upwards. Larch is the quickest variety of home-grown structural timber in reaching maturity, requiring about sixty years from the time of planting before it is fit for use. It is the most profitable timber to grow, and is the best and most durable of our native softwoods. Poplar is of more rapid growth, but is not generally considered to be suitable for structural work.

Timber is composed almost exclusively of organic matter, and, as a consequence, it decays very rapidly when subjected to the alternate influence of rain and sun. It is calculated that the inorganic portion of the tree does not exceed more than 2 per cent. of the whole after the log has been thoroughly dried. Thus it is of the utmost importance that timber should be employed only under conditions where it will be protected from the direct action of the elements either by a substantial coating of paint, creosote, tar, or some similar non-decomposable matter, or by being completely covered with some more durable material, such as lead or zinc. On no account, however, must timber be painted or coated with a liquid or plastic material which hermetically seals the pores while it is in a damp condition, as the moisture would then be imprisoned in the interior of the wood, and would constitute a potential source of trouble that would ultimately result in decay. When it is impossible to postpone any projected work until the timber is quite dry it should be painted on three sides only, the remaining side, and especially the ends, being left bare and exposed to the atmosphere, so that the moisture will have every opportunity to evaporate. Evaporation takes place much more freely and rapidly from the end of a baulk than from the sides, as the moisture has a better chance to escape through the open ends of the tubes than by penetrating sideways through the cell walls. The practice of creosoting timber while it is wet is to be avoided for the same reason, and, in addition to the imprisonment of the moisture, the penetration of the oil is hindered to some extent, and thus the efficiency of the process is considerably reduced. Timber that has been thoroughly dried before it is used either for joinery or carcassing work has its durability considerably increased, and is less liable to splitting and warping, but the drying must be carried out carefully and scientifically, or the timber will be case-hardened, and a great risk exists of the material being completely ruined for good class work. The whole question of drying and impregnating timber against decay, is fully discussed and explained in a treatise on the subject that is now being published as a companion to this volume,* in which many different processes that are designed to prevent decay or mechanical injury from the attacks of insects are described and illustrated.

The organic matter of which timber is composed at the commencement of growth is principally cellulose, and this is ultimately converted into lignin by the action of the mineral salts which are absorbed from the earth by the roots. This constitutes the true wood. In a series of experiments that were carried out by the United States Department of Agriculture some years ago to determine the comparative constituents of wood and cellulose, it was found that the composition of the two substances was mainly as follows:—

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* "The Seasoning and Preservation of Timber."

	100 lbs. of Wood.	100 lbs. of Cellulose.
Carbon	49 lbs.	44·4 lbs.
Hydrogen	6 ,,	6·1 ,,
Oxygen	44 ,,	49·3 ,,

In order that the test might be as accurate as possible, the wood had previously been thoroughly dried at a temperature of 300° Fahr.

The decay of timber that is exposed to the alternations of the weather is fairly rapid, even in the best qualities, but decomposition is considerably accelerated if the timber has an excess of sap, even when precautions have been taken to ensure that it is thoroughly dry before use. The presence of the actual sap is often considered to be one of the principal causes of wet rot, owing to the fermentation of the juices which is set up by the influence of wet, but this is only correct in a relative sense, as timber may decompose very quickly, even when all sap and moisture has been removed. The reason for this is because it is the sap *wood* that decays, which, being nothing more than immature tissue, possesses less durability as compared with the heartwood, even after it has been dried and treated by a preservative process. Sapwood that is used in a dry and well-ventilated situation will endure for quite a long period, provided that it is kept permanently dry, but the ratio of durability as compared with the heartwood remains the same. Timber of this quality should only be used for the roughest and least important work, and if possible it should be rejected altogether. It must be admitted, however, that cases have been known where sappy fir joists have been found in quite good condition after the lapse of 150 years, but this only proves the value of suitably dry conditions rather than the actual durability of the timber itself. The almost incredible number of years which sound English oak timber will endure, when it is situated in dry and otherwise favourable surroundings, prove conclusively the supreme necessity for the most careful selection of the timber when it is required for use in buildings of a really permanent nature. This is well illustrated in the wonderful roof of Westminster Hall, which is more than 500 years old, and has recently been restored so that it is anticipated that many more years will pass before it will have to be replaced. The roof is described in Chapter VII.

In the days before steel girders had become recognised as an orthodox and effective substitute for wooden beams, and before the idea of reinforced concrete had been heard or even thought of, oak was invariably used for all classes of buildings, from the stable and the cottage to the most elaborate mansion or royal palace, and the enormous beams that were employed for spanning over the openings, or often merely as a bond for holding the large masses of masonry together, can be found to-day in such a perfect state of preservation, that it seems almost impossible to realise that they have been in the same position for centuries. The effect of age, however, instead of encouraging decomposition, has been merely to cause the timber to become harder and darker, and to all appearance more durable, than ever. Instances of this can be found in any of the old castles and houses that are scattered about the country, and which appear to be good for centuries more of wear and tear, provided that no adverse circumstances are allowed to hasten their decay.

The liability that exists with all kinds of timber to suffer under the attacks of insects and parasites of various kinds, arises from exactly the same cause that is responsible for its decomposition in the presence of moisture, *i.e.* from its organic nature, but the phenomena which are responsible for its destruction vary in different cases and operate in different ways. Timber that is entirely submerged under water will remain uninjured by decay for an almost indefinite number of years, provided that it is not subjected to the action of the air; the cause of decay when timber is exposed to the elements lies in the action of air and water alternately, and if it were not for this, the timber would keep sound for a very long time. Similarly, complete protection against wet and a free circulation of air all round the timber will have the same result.

The beneficial effects of this freedom from alternate exposure to wet and dry conditions have been illustrated in a most remarkable manner by a very interesting discovery that was made in California a few years back. A piece of timber was there unearthed which, it is estimated, had been buried for approximately a million years. It was sent to the Forest Products Laboratory for examination, by Mr. C. L. Hill, Assistant District Officer of the United States Forest Service. According to Mr. Hill's report, "The wood was taken from 500 ft. underground in a tunnel of the California-Hawaiian Development Co. in Long Canyon, Diabolo, Meridian, California, on September 17th, 1920. The log was buried in the gravels of a Tertiary stream bed about 12 ft. under the lava cap of the grade flow which terminated the Tertiary period. It is, therefore, at least a million years old, and is rather remarkable in the fact that it is neither silicified nor disintegrated, except as to the softer spring wood of some annual rings."

That wood can exist in this remarkable state of preservation for such an unheard-of period as is indicated in the report seems to be almost unbelievable, but discoveries of such far-reaching importance, and under such unpromising conditions, are becoming so common nowadays that it is hardly safe to dispute, or even to seriously question, any statements of this kind without the most reliable evidence to the contrary.

Submersion under water, however, while acting as a most effective protection against the decomposition of organic matter for many years, exposes the timber to other dangers which are not less serious, as it provides an easy avenue of attack for marine insects and parasites. The *Teredo navalis* is perhaps the worst of these, as it is one of the most destructive enemies of timber from a mechanical point of view. The *Teredo*—which is commonly called the "ship worm"—does an enormous amount of damage to the timber piles in dock and harbour work, to the bottoms of wooden ships, and to dock gates, by boring its way into the timber and riddling it with burrows from end to end of the submerged portion. White ants (*Termes bellicosus*), on the other hand, only exist on dry land, and principally in tropical countries, and even though the timber may be effectively protected against decomposition from the effects of moisture, the very conditions that are responsible for this freedom, provide the opportunity for these destructive pests to get to work and to literally eat up the timber in a remarkably short space of time. The death-watch beetle is another destructive insect, with which we in this country are more familiar ; its ravages are normally carried on under cover, and result in the most disastrous consequences. A full description of this unwelcome visitor is given in the second part of this volume. Soil bacteria are responsible for the rapid decomposition of fence posts, and any timber that is buried beneath the ground ; they produce the phenomena that were described by Liebig, the great German chemist, in his theory of decomposition called "Eremacausis," as being due to slow combustion or molecular motion, and not to the action of living organisms. This theory has since been disproved.

There are also various members of the fungus class which attack timber and cause a good deal of destruction. Some of these are found on the living tree before it has been felled, while others flourish only in buildings after the timber has been converted and used for structural purposes. The fact that most fungi and other parasites nearly always commence their destructive operations on the sapwood, and then spread to the heartwood as they become more robust and self-supporting, emphasises what has been repeatedly pointed out in these pages, *i.e.* the necessity for using only the best grade of timber for all structural work of any importance, and points to the dangers that may arise from any neglect of this precaution.

During the last quarter of a century the use of timber has very largely decreased on buildings of the better class, especially on the large blocks of shops and offices that have sprung up so quickly in our large towns ; factories, warehouses, and workshops are also constructed with very little timber nowadays, as the roofs are built of steel, the floors are composed of reinforced concrete, with breeze slabs for the partitions, and the windows are in many cases of a light iron construction, so that there is very little besides the doors and the internal fittings, for which timber is required. Even these are often made of steel on account of the danger of fire, and it does not require any great effort of the imagination to visualise the type of building that will be erected in the near future, in which not a foot of timber is employed, if the present rate of progress is maintained. This revolution in the methods of building construction has been introduced chiefly for the purposes of fire prevention, while the lower cost of production of many articles that are manufactured to standardised patterns out of sheet steel provides an additional inducement for their employment and encourages their use. Whether these changes are for the better or for the worse it is hard to say, but the passing of the good old type of timber floor or roof is to be regretted from many points of view, and it is to be sincerely hoped that the " hewer of wood " will not be altogether driven out of existence, in favour of the newer system of steel construction, in the same manner as so many of the old time craftsmen have been effaced, by the march of civilisation. Fortunately a good deal of timber is still essential for the erection of the residential class of building, although even this preserve is being threatened with opposition from the freak composition structures that are now being taken up by many whose lack of a specialised acquaintance with real building construction deludes them into the belief that anything that *looks* like a house necessarily *is* a house. The terms, however, are not altogether synonymous.

Timber, it must be admitted, is specially liable to decomposition, and when it is employed under conditions which are not suitable for ensuring its durability, little wonder can be felt if the material is looked upon with suspicion in many cases where the greatest possible permanence is of the first importance. The fact that timber that is dry when it is built into place, and that is kept dry afterwards, will endure for an almost indefinite period, should be borne in mind, and the certainty that no timber, in whatever condition or of whatever variety it may be, can withstand damp surroundings without suffering rapid deterioration, should be taken into consideration when it is employed for any of the manifold purposes for which it is so peculiarly fitted.

CHAPTER II

DRY ROT : ITS PROPAGATION AND DEVELOPMENT

IN the inanimate world, as well as in our own particular domain, some of the greatest results often arise from very small beginnings, and this fact is exemplified in every phase of existence as we know it to-day. The cumulative effects of most of the laws of Nature, if allowed to proceed unhindered to their logical conclusion, often reach to dimensions that would appear to be at the least improbable at the commencement. The old saw which relates how " for the want of a nail the shoe was lost," and so on, to the ultimate forfeiture of the very kingdom itself, while, no doubt, being merely a figment of some ingenious person's brain so far as actual fact is concerned, yet emphasises very forcibly the inevitable results of apathy or neglect in any of the ordinary duties of civilised existence. Neglected cultivation is bound to result in poor and ever diminishing crops ; neglected business only too often leads to the bankruptcy court ; the failure to perform some trivial, but important, duty reacts to such an extent on the smooth working of an industrial undertaking that the whole business is disorganised, causing widespread loss and annoyance, which can never be adequately compensated ; while even neglected recreation and pleasure is reflected in the loss of tone and vitality in the human system, and all because of some avoidable lack of will-power in the first instance. Such examples as these serve to illustrate how essential is the principle of thoroughness in all stages of life. It must be recognised, however, that thoroughness is not the foremost attribute of the present generation, and that it is not only too often ignored by the person who is responsible for seeing that some particular operation is carried out in the best possible manner, but that it is very often lost sight of by the workman to whom falls the duty of carrying out the work.

The principle of thoroughness, however, applies in more than one direction : it does not refer solely to the manner in which any particular piece of work is executed, but it is concerned in an equal degree with the provision of suitable materials for the purpose, and with the arrangement of the best and most effective manner in which they can be employed.

From the remarks that have already been tabulated on the structure and composition of timber, it is fairly obvious that it is not suitable for use under all or any conditions that may possibly arise. When timber is kept perfectly dry, or permanently wet by continued immersion in water, it is not liable to decomposition to any great extent, but as soon as both of these influences are permitted to operate intermittently trouble is bound to come. So far as the present chapter is concerned, however, this consideration does not necessarily hold good, for the spread of dry rot can take place in a situation which is quite dry as well as in one that is wet. This must not be taken to mean, however, that moisture is not a necessary factor in the problem of dry rot, as it is actually one of the primary conditions that are required for its propagation, but it should be understood that once the disease has obtained a secure footing, in surroundings that are favourable to its development, the presence or absence of moisture in the vicinity is not so essential, to enable it to spread and to attack the whole of the timber to which it has access.

The term " dry rot " is rather apt to convey a misleading impression with regard to the nature of the disease and the conditions that are necessary to enable it to thrive, as it would appear to the uninitiated that the decayed condition of the timber is a product of drought, instead of being directly attributable, in its earlier stages at least, to the presence of moisture, acting in combination with certain other essential conditions. As a matter of fact, dry rot is a very highly infectious fungoid disease, which is as quick to attack timber as scarlet fever or measles is to attack the human frame. But although the disease, when it has reached a state of maturity, assumes the form of a fungus, it must not be taken for granted that all fungi are necessarily of the same virulent nature, for the majority of the species are quite harmless so far as the development of dry rot is concerned. It must not be forgotten, however, that in those places where fungi abound dampness will generally be somewhere in the vicinity, and this should be taken as a warning that attention is urgently required to remedy the existing conditions and to dispose of the cause of the dampness as quickly as possible.

There is quite a definite distinction in the condition of timber that has been attacked by dry rot and by wet rot, and in the causes by which these conditions are brought about. While the former is the result of the action of a vegetable parasite which produces certain well-defined changes in the timber, the latter is brought about by the presence of moisture acting directly on the constituents of the fibres and ending in the decomposition of the wood. In the case of wet rot, the intermittent action of air and water results in the oxidation of the lignin which constitutes the cell walls of the true wood, so that it is decomposed into simpler elements, the actual breaking up being due to the agency of bacteria operating on the chemical constituents of the wood. Dry rot is caused by the extraction of a portion of the mineral content by the roots of the fungus. The ultimate results of both types of decay are of a very similar nature, although they are produced under different conditions and have quite a different appearance.

There are at least three distinct types of fungus which are responsible for causing dry rot in timber after it has been converted and used for structural purposes. These are *Merulius lachrymans*, *Coniophora cerebella* and *Polyporus vaporarius*. The most common variety that is found in dwelling-houses in this country is *Merulius lachrymans*, which, besides being the most widespread in its distribution, is by far the most deadly and malignant of the three. A tremendous amount of damage to property is caused by this species, the total of which probably exceeds that from any other source, with the possible exception of dampness; the latter, however, affects not only the timber, but also the brickwork and plaster of the building, and the extent of the damage is thereby increased. Dry rot is essentially a disease that is connected with timber alone, for, while its ramifications may extend over any other of the various substances in the building, they merely form a support to which it is attached and are not themselves affected by the disease in any way. At one time it was thought that the spores of *Merulius lachrymans* would not germinate except in the presence of an alkali, as it had been found impossible at the time to cultivate the fungus except under these conditions. This theory has since been shown to be incorrect, and it has been demonstrated that the spores will germinate even in a slightly acid solution. In the older class of property, however, the growth of the fungus is probably encouraged to some extent by the alkaline nature of the mortar, which is often more or less disintegrated and in a very bad condition, and this may be partly responsible for its luxuriant growth.

The disease is propagated by means of very minute spores, which are about $\frac{1}{3000}$ in. in diameter, and are therefore only visible to the naked eye when they are together in very large numbers. They then take the form of a fine brown dust. The spores are very tenacious of life, and, provided that they are kept quite dry, they may lie dormant for many months without losing the power of germination. It is this vitality which gives such an insidious nature to the disease, and when it is coupled with the microscopic dimensions of the spore, it enables the infection to be spread from place to place without any visible evidence of its presence.

Dry rot may be communicated to the timbers in a house that so far has not been infected, in several different ways. The spores may obtain an entrance by floating about in the air until, in course of time, they are deposited in surroundings that are favourable to germination. They may also be introduced on the feet of workmen who are employed about the place, and who may have previously been in contact with the fungus in some other locality. Tools that have been used for cutting infected timber may also be the vehicle by which the spores obtain admission, and, what is probably the most common source of introduction, the timber may have been infected before it was brought on to the site, and may be in an unseasoned condition, which only invites trouble.

There are four conditions that are necessary for the successful germination of the spore and for the development of the fungus; these are darkness and a certain degree of warmth combined with a damp and stagnant atmosphere. The two latter are the most important of the four essential conditions, and in the absence of either it cannot make very much progress. A moderate temperature is necessary, as with very little more than 100° Fahr. the disease is unable to exist, and ultimately it dies out. Falck computes that the highest temperature at which *Merulius lachrymans* can thrive is from 79° to 80°

Fahr. Low temperatures, on the contrary, have little effect on its growth, and even freezing point is not sufficient to exterminate the disease. The requisite conditions are only too frequently found in dwelling-houses, especially in the space beneath the ground floors. Darkness, of course, is inseparable from such an out-of-the-way place, and cannot very well be provided against, while the temperature is usually somewhat above the normal, owing to the heat that is given off from the fire in the room above ; both darkness and warmth, however, are more or less contributory rather than primary causes, and they do not exercise the same influence on the progress of the disease as a damp and stagnant atmosphere. Dampness is very common in old property, owing to the general absence of a damp-proof course in the walls, while the lack of adequate ventilation is also quite usual, not only in the older type of residence, but also in much of the newly built property that has been erected in recent years. Under such favourable conditions as these, it is not surprising if dry rot is rampant, and that it spreads rapidly over the entire vicinity. The only remedy that offers any guarantee of success, when once the disease is fairly entrenched on the premises, is to take steps that will deprive it of its means of subsistence, so that it is forced to die out in course of time.

There is some little difference in the moisture requirements of each of the three varieties of fungus mentioned on p. 28. *Coniophora cerebella* needs a considerable degree of dampness for its subsistence ; on the other hand, *Merulius lachrymans* needs practically none at all once it has become established; while quite a small amount suffices for the needs of *Polyporus vaporarius*. The reason for this difference will be explained later on. It is most fortunate that both the actual and the contributory conditions which are essential for the successful propagation and development of the dry rot fungus are so well known, for, once the cause of a malady is discovered, it is a comparatively simple matter to take effective precautions against any trouble arising from its spread in the future. Thus, in the event of the timber falling a victim to the disease, the best means of dealing with the situation can be devised with a fair prospect of success in effecting its eradication. One of the principal reasons why so much dry rot exists in the country lies in the fact that many people do not treat the subject with sufficient respect and consideration, and deal with it as if the problem were of quite a simple nature. This can only be disastrous, as nothing but the most drastic measures, put into immediate operation and carried out with the most meticulous care, will give any reasonable hope that the building in question can be freed from the grip of the disease. The neglect to take proper precautions for guarding against a future outbreak during the construction of new buildings of any kind where timber is employed, will create a potential source of trouble which may materialise with very undesirable results at some time or other.

The uncertain and erratic nature of the disease was very clearly illustrated in a large mansion in North Wales that was inspected by the writer a few years ago. The building had been erected at considerable expense not a great while before, and the interior fittings were of the most ornate and costly description. Suspicions, always hard to allay, were entertained that dry rot had somehow or other obtained a hold on the woodwork, and not a little alarm was naturally felt as to the ultimate outcome of the suspected attack. A close and systematic examination of the premises from roof to cellars revealed the fact that there was very little visible evidence pointing to the presence of dry rot, yet a few simple tests demonstrated unmistakably that it had certainly effected an entrance, and that the alarm was amply justified up to a certain point. Evidence was forthcoming of the presence of the disease in several parts of the house, but the most noteworthy feature of the case was, that in neither of the rooms was the trouble connected with the attack in the adjoining apartment, each case being quite separate and independent of the others. The upper rooms were in the same condition as those on the ground floor, but nowhere was the trouble very far advanced, and comparatively little damage had been done on the whole. In nearly every instance the attack was located in the corner of the room, and had not at the time spread very far from the place of origin. The evidence pointed not so much to bad construction as to the use of unseasoned and probably infected timber in the floors when the house was built, and there is little doubt that this was the cause of the series of outbreaks that had occurred.

It has already been observed that the form of dry rot that is most commonly found in dwelling-houses is *Merulius lachrymans*, and that this is also the most virulent and destructive of the various species. *Merulius* is quite domesticated in its habits, and has probably never been found in existence on the tree before it has been converted and stacked. *Polyporus vaporarius*, on the contrary, is frequently met with in a wild state, and can often be found in a flourishing condition on the tree before it has been felled and conveyed from the forest to the mill. It is probable that this is very often the means whereby the spores obtain an introduction into a building, as they are blown into the cracks and crevices of the timber and remain there during its transport and subsequent conversion, only waiting the opportunity to break into life.

When the spore has been deposited in an environment that is suitable to germination, it commences to expand. Two or three swellings are produced on its edge, and these in time develop into very fine rootlets, or hyphæ, which continue to grow rapidly until they take the form of long, tenuous strands, running here and there over the timber. This is the commencement of the work of destruction, and from thenceforward it goes on unceasingly and quietly, following out a definite line of action in all its wanderings, until it is either destroyed by the measures that are taken for the purpose, or else it expires for want of further material to attack. The latter contingency is only arrived at in extreme cases, however, as the timber would collapse long before it was all consumed.

The hyphæ are the direct instruments by which the timber is destroyed, as they bore into its surface by exuding a secretion from their tips, which rapidly opens a way for them to penetrate into the interior of the timber. Once an entrance is effected, the hyphæ spread in different directions, burrowing along the cells and passing through the cell walls in their search for nutriment. This they obtain in the form of the mineral salts and nitrogenous matter which are contained in the substance of the timber. It is these burrowing hyphæ which destroy the wood by breaking up the lignin into simpler compounds until it is utterly and irretrievably ruined. The attacks of some species of fungus are confined chiefly to coniferous timbers, but *Merulius lachrymans* is more catholic in its tastes, and its attentions are distributed with less discrimination amongst most kinds of wood, from the softest variety to many of the hardwoods ; whatever the species of timber that is concerned, the attack is fatal if it is not dealt with at once. Thus there are, as a rule, none of the timbers that are used in ordinary building construction which can claim immunity from the attack of dry rot, unless some suitable measures have been taken for their protection. A serious indictment enough, to be sure !

The spore then, having germinated under conditions which favour its development, and having commenced operations against the timber on a wholesale scale in its efforts to obtain a sufficient supply of nourishment, proceeds at the same time to send forth other rootlets in quest of further opportunities of attack. These hyphæ confine their activities for the moment to the exterior of the timber, spreading over the surface in long cords or strands, at the same time as the others are eating their way into the interior. They are not harmful so far as their actual presence on the timber is concerned, and they serve a useful purpose by presenting very strong evidence of the destruction that is going on within. But, however, they have a much more definite purpose than wandering aimlessly over the timber, for at intervals they throw out other hyphæ, which penetrate into the surface and consume the interior in exactly the same way as those which first appeared. Thus the deadly work goes on unseen, unheard, and in all probability unsuspected, until the damage is so extensive as to become perceptible to any but the least observant person. The ramifications of the hyphæ are very wide, and they may, and often do, extend for many yards.

By the time this stage has been reached the spore, having fulfilled its purpose, becomes exhausted and withers away, leaving the rootlets entirely dependent upon their own exertions and their own inherent capacity for obtaining enough food for their needs. That they are fully capable of carrying out this duty is only too apparent, as the hyphæ continue to support themselves, to extend the radius of their activities, and ultimately to reproduce themselves in the shape of a further generation of spores.

While this is going on patches of a fine mould appear on the surface of the timber which very much resemble tufts of down. These tufts have long, silky filaments, which, starting from a common centre, radiate outwards, forming a ball of beautifully white and soft vegetable matter, very delicate in texture and appearance, and fairly regular in shape. The patches may appear in random positions, and when two or more are situated in close proximity to each other, in course of time they increase in area and merge into one another, forming an irregularly shaped patch (see Fig. 2). As the disease progresses the superficial hyphæ weave themselves into a thick, compact mass, which spreads over the timber to some considerable distance, throwing out cords in all directions, until the whole surface in the vicinity is completely enveloped in the network of roots. As a general rule, it is found on the joists and attached to the under-side of the floor boards, where it flourishes exceedingly and attains to considerable dimensions. This is the *mycelium* of dry rot (Fig. 2), and constitutes the reproductive portion of the disease.

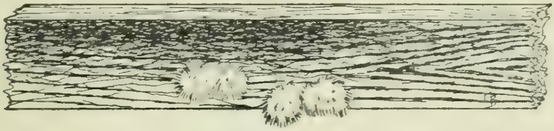

FIG. 2.—Mycelium of Dry Rot.

In its later stages the mycelium becomes so tight and matted that it assumes the character of a fungus. It is dark brown in colour, is pitted all over with very small holes, and the surface is covered with a series of ridges or corrugations which extend over the whole of the fungus. Its appearance is now very similar to that of a fine-grained sponge, but it is flat, and adheres tightly in sheets to the surface of the timber by its under-side. The spores are produced on the edges of the corrugations in countless numbers, and when they have ripened and fallen off, the ground beneath is covered with a fine brown powder. This is called the *fructification* of the *mycelium*, and is the final stage in the life of the plant ; it may, however, continue to exist and to spread for considerable distances as long as there is fresh timber that is open to the attacks of the wandering hyphæ. The structure of a cross-section of the fructification is somewhat loose, and it is composed of a dense mass of hyphæ, which continue to creep along the under-side of the joists and boards, showing a decided preference for the angles between the two. Fig. 3 is an illustration of the fructification, showing the white edges which are characteristic of *Merulius lachrymans*.

A special peculiarity which is possessed by *Merulius*, and which adds considerably to its powers of doing harm, is its habit of spreading over any substance, such as stone, brick, or metal, that it may encounter, although the substance to which it adheres may be quite dry and altogether unable to provide any means of subsistence ; thus its range of activity is very much extended, as the roots can pass over long distances in their search for fresh fields of operation without suffering in any way from the absence of moisture. This habit of wandering over dry places may appear to be opposed to what has been said regarding the nature of the disease when the fact is considered that the spore can only germinate in damp surroundings, and that a continuous supply of moisture is essential for the existence of the fungus. The explanation, however, is com-

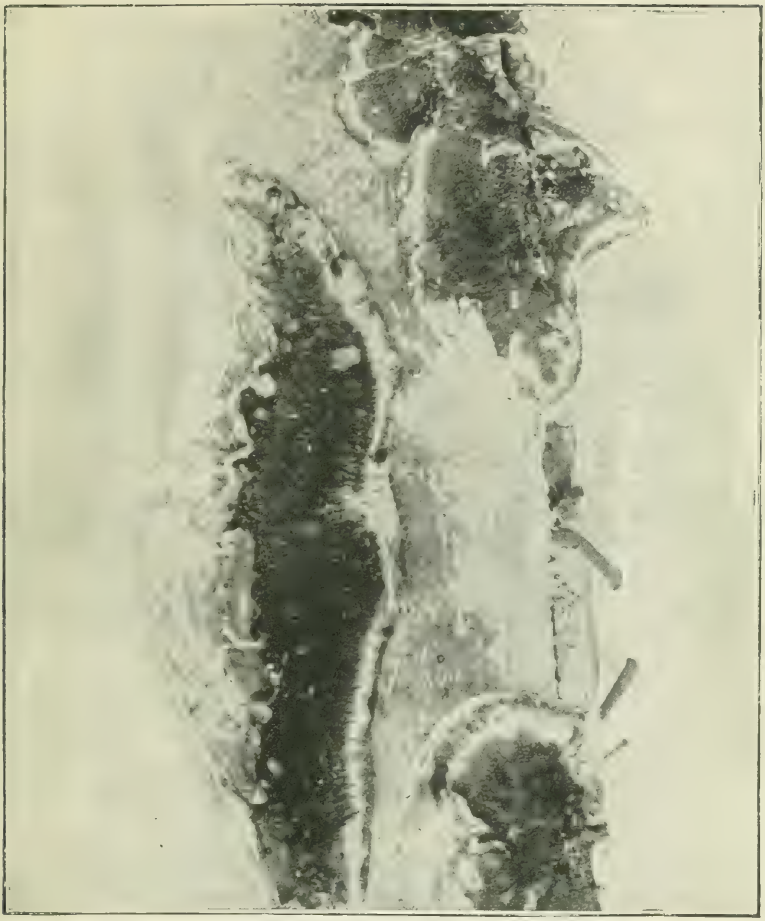

FIG. 3.—Fructification of the Mycelium of Dry Rot.

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paratively simple when the whole facts are taken into consideration. In the first place, *Merulius lachrymans* is provided with the means of producing moisture for its own use by converting a portion of the timber into carbon dioxide and water ; hence it is to a great extent independent of any further supply when once it is fairly established. As a rule, however, the timber to which it is attached is more or less permanently damp, so that there are two distinct sources on which it can depend for its needs. In addition to this, the mycelium condenses the moisture which is always present in the atmosphere, absorbing it and passing it on to the hyphæ, no matter what distance they may have traversed. This twofold capacity for producing and attracting water is so active that in time the moisture exudes from the surface of the fructification, and from the tips of the superficial hyphæ, and hangs there in drops or tears. It is this peculiarity which has given the specific name *Lachrymans* to the fungus, from the Latin *lachryma*, a tear. The capacity for producing its own supply of water is obviously of the greatest service to the hyphæ in their wanderings away from the base, and assists the disease to spread in all directions over considerable areas. It is also enabled to penetrate into, and even through, brick walls, and to burrow some distance into the earth, the necessary nutriment being obtained regularly from more convenient positions. Thus the particular importance of excluding all moisture, both from the atmosphere and from the structure itself, is forcibly illustrated.

Another consideration that is only second in importance to the last is that *Merulius lachrymans* not only attracts moisture from the atmosphere for its own especial use, but also passes the moisture on to the timber, which, although perhaps perfectly dry in the first place, quickly absorbs it and becomes damp ; thus decay is hastened by unsuitable conditions, which may be produced quite independently of its own immediate surroundings, and the progress of the disease is accelerated at the same time.

The different species of dry rot can be identified by the colour of the cords and the mycelia. In *Merulius lachrymans* the fructification is of a rusty brown colour, with an extremely evil-looking appearance, the margins being of a whitish tint, while in *Polyporus vaporarius* it is more of a white, verging on to cream or flesh colour. The latter is also smooth compared with the corrugated surface of *Merulius*. The fructification of *Coniophora cerebella* is brown, and resembles *Merulius* so much that it is often impossible to distinguish the difference between the two at a casual glance. The structure of the cords varies somewhat, but this medium of identification is not always sufficiently marked to readily distinguish between the varieties.

When a building has been attacked by dry rot, the danger is probably not suspected until the disease has had plenty of time to take a good hold on the timbers. The fact that dry rot can only, as a rule, exist in dark and out-of-the-way places, makes it extremely difficult to discover that anything is amiss until the disease has progressed so far as to call for instant attention. The first indications of trouble will usually appear in the floor boards, skirtings, and later on in the wood panelling on the walls, when the following are the most prominent signs that will be in evidence : The boards begin to shrink, and they may exhibit a tendency to curl up transversely, this last being specially noticeable in the skirting, as it is not fixed so securely to the wall as the floor boards are nailed down to the joists. Later on cracks will appear in the surface of the boards ; some of these may run parallel with the grain of the wood, while others will open across the grain, as shown in Fig. 4, thus making the timber appear as if it had been severely scorched or burnt. The boards generally have a dull and lifeless appearance, and they give out a dull, hollow sound when struck with a hammer. They are likely to become stained with red or brown streaks and to look generally dirty all over. When these indications are seen either singly or together,

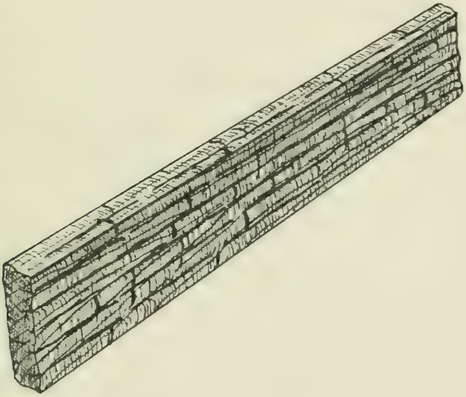

FIG. 4.—Timber badly attacked by Dry Rot.

no time should be lost in making further investigations. The timber should be tested in various places by pressing a bradawl or the blade of a penknife against the surface, and if the disease has progressed very far, it can be pierced without any difficulty. At this stage no further doubt need be entertained that the dreaded dry rot is present, but to make doubly sure, and to ascertain the extent to which it has spread, a board should be removed here and there, so that the actual conditions beneath the floor can be seen.

Skirting boards, being painted, do not show such clear indications of trouble as the floor boards, as the discolouration cannot be seen, and the cracks are likely to be more or less concealed by the paint. On taking down the skirting, however, it will probably be found that the back of the board has completely rotted away, leaving little more than a thin shell of wood which is held together by the paint, in front. The back will no doubt be covered with strings of hyphæ, and if the disease has been in existence for any great length of time, the fructifications may be found clinging to the timber. If one or two floor boards are lifted, so that the space beneath is thrown open to inspection, a damp, earthy smell will pervade the apartment, this being due to the moist air and to the peculiar odour that is given off by all fungi.

The effects of a bad attack of *Merulius lachrymans* on joists and flooring are of a most far-reaching and destructive character. The hyphæ which have penetrated into the timber and spread in different directions will have caused the most disastrous change to take place in its condition. Instead of being of a solid and more or less flexible nature from the numbers of fibres which stretch side by side throughout its length, the timber has become quite short and brittle, and the inside is so soft that it can easily be ground into powder between the finger and thumb. The outside may show very little evidence of the havoc that has taken place within, beyond a certain amount of discolouration; and as the cracking only occurs in the later stages, the wood may often be to all appearances as sound as ever until a closer examination reveals the unwelcome truth. That the strength of the timber is very much reduced goes without saying; in fact, in course of time it becomes so weakened that the slightest extra stress might cause it to collapse without warning, and the most serious danger to life and limb would be entailed. In the earlier stages of dry rot, the destruction of the fibres has naturally not progressed to this extent, but that it has caused a sufficient change to take place in the nature of the timber, so that its strength is proportionately reduced, can be taken for granted.

From a series of tests that were carried out a few years ago at the Forest Products Laboratory of Canada it was ascertained that, even when the timber had only suffered to a slight extent from the depredations of dry rot, its compressive strength across the grain was reduced as much as 20 per cent. below that of a similar species of timber that was quite free from disease. When it can be conclusively proved that a very slight attack will cause such a serious reduction as this in a comparatively short time, it will easily be realised to what extent the strength of timber is impaired when it has been badly infected and has suffered from the attack for a long period.

One of the characteristics of *Merulius lachrymans* is the unusual rapidity with which it spreads and the thoroughness with which it carries out its deadly work. A case in point occurred in the Reading district some little time ago, in which a new deal floor had to be taken up and entirely renewed only nine months after it was originally laid down; this was due solely to the effects of dry rot. In another case, this time in Hampshire, a number of sound English oak joists, about 3 ins. thick, that were used for supporting the floor over a cellar, were reduced to such a powdery condition in the space of a year or two, that the timber could easily be pierced with a lead pencil. In this case the joists had been cut from unseasoned oak, and the cellar was particularly damp, but, although it was provided with a window, there were no facilities for encouraging a free circulation of air around the timber, so that the atmosphere was permanently stagnant, and thus ideal conditions were created for the development of the disease.

Another difficult aspect of dry rot arises from the wandering propensities of the hyphæ. Not satisfied with destroying the timbers beneath the floors, they very quickly spread round the edges of the boards to the skirting, which in turn falls a victim to their rapacity. From here the hyphæ continue their progress to the wood panelling higher up, or, in the absence of this type of finish to the walls, they creep up behind the architraves and door linings, and every bit of timber they touch is involved, at least to some extent, in the general destruction. It should be remembered, however, that it is only in unventilated places that any injury is caused to the woodwork. That the hyphæ can pass over or through plaster or brickwork is shown by the common occurrence that timber which is quite isolated from any other woodwork in the building, such as the window frame and linings, cupboards, and any other joiners' work that may be fixed on the wall, frequently suffers from the attention of the hyphæ. This inherent tendency to rove unseen needs careful attention when dealing with such a disease as dry rot, or its presence may very easily be overlooked until considerable damage has been done.

Buildings that have been used as stables at any time are specially liable to develop dry rot, as the ammoniacal gases that may rise from the soil for some years after their specific use has been discontinued will be apt to encourage the germination of any spores that may have obtained admission when the floors were laid. Particular care must be taken, when laying wood floors in a building of this kind, to adopt such measures as will effectually prevent the germination of the spore, or that will prevent its further development if germination should by any means take place. The steps that are necessary to ensure freedom in this respect will be fully described in the next chapter.

Only very brief consideration will be required before deciding on the necessity for adopting remedial measures when the indications that have been enumerated above are found to exist. Little advantage will be gained by a lengthy deliberation as to the particular species if the timber is found to be covered with a network of hyphæ or fungus, as the chances are that the offender is *Merulius lachrymans*, and in any case it is best to take the same measures to ensure safety in the future. Even if it is the least harmful of the three species of dry rot, no quarter must be given, as none will be received, and it would only be courting disaster to adopt half-hearted measures at such a critical time. It would be well, however, to make quite sure that the trouble really is dry rot, as superficial evidence may at times be somewhat misleading. The presence of roots alone does not always provide conclusive evidence of the existence of dry rot, as they may belong to some plant or creeper that is attached to the external wall of the house. Roots of ivy and other vegetation will often creep through a crevice in the brickwork and spread over the timbers for some little distance if there is any moisture which they can obtain, and they may be mistaken for the hyphæ of dry rot at a casual glance. This situation of course needs very little attention beyond severing the offending roots and making the brickwork good as far as is necessary. As, however, the presence of fine, straggling roots is one of the first things to look for when searching for signs of dry rot, the investigations should be carried further, with the object of discovering the presence or absence of the fructification. The timber should be thoroughly tested with a knife or bradawl, and if it is easily pierced and is found to be in a dry, powdery condition inside, remedial measures should be put in hand as soon as possible.

It should be remembered that the fungus of dry rot is a low form of plant life which is extremely infectious, and therefore very easily spread, and it must always be treated as such. As an aid to determining the particular species that is under consideration, the colour of the hyphæ should be noted ; those of *Merulius lachrymans* are of a greyish white, changing perhaps later on to a dirty yellow, while those of *Coniophora cerebella* soon turn to brown, and ultimately become nearly black. Each type is distinct in the formation of the hyphæ, but the differences are, on the whole, not easily detected by the average person. The massing of the cords into the thick, compact mycelium is one characteristic that is peculiar to this species of vegetation alone, and the subsequent fructification of the mycelium supplies the last and most conclusive link in the chain of evidence as to the family of which it is a member.

CHAPTER III

THE PREVENTION OF DRY ROT IN NEW BUILDINGS

FROM what has been said on the subject of dry rot it will readily be conceded that prevention is better than cure in this case, equally as much as it is in any other of the multitudinous diseases that are apt to attack mankind or their achievements. It is perfectly obvious that a very much larger expenditure of time and money must inevitably be incurred in effecting a permanent cure of any person or substance after it has once become a prey to disease than would have been necessary if the attack had been prevented in the first place. It is one of the many valuable provisions of Nature that most of the dangers to which we are exposed can be avoided with little trouble if steps are taken to guard against them before they have materialised, but procrastination is very often fatal, and it usually spells increased difficulty at least in the future.

It has been said that " to err is human," and when the general body of the public are so sadly deficient in their knowledge of the cause of many of the more undesirable experiences that fall to the lot of mankind, as they are to-day, it is hardly surprising if things are allowed to take their own course until circumstances combine to prove that this policy is entirely wrong by the disastrous results that ensue. The neglect to take proper precautions against disease of various kinds does not altogether prove the absence of common-sense in the individual, but in many cases it is due entirely to ignorance of the subject concerned, so that the individual himself cannot rightly be blamed.

On the other hand, if a man were to be expostulated with for sawing off the branch of a tree on which he was sitting, and the risk that he was running was pointed out, he would naturally profit by the good advice that was offered, and would take steps to avoid the danger with which he was threatened by his own heedlessness, or he would have to take the consequences. In the same manner, all those who may be the possessors of house property, or who may be responsible to the owner for its upkeep and safety, would be well advised to take a few hints on the subject of the deterioration of the building, where their own personal experience may be lacking ; they will thus undoubtedly benefit in the future, provided that whatever steps are necessary are put into operation without loss of time, and carried out with that careful attention to detail which should always be observed.

A good deal of organic material goes to the building of a house, and this, if not protected against the attacks of its natural enemies, will very quickly deteriorate. The bulk of this organic matter is timber, and it is apt to suffer in many ways if it is exposed to attack without protection of some kind or other. A large proportion of the timber that was employed in the erection of a building a century or more ago has been eliminated in the modern type of structure, so that less danger exists of trouble arising from decomposition. In the smaller class of dwelling-house that is erected to-day, however, the era of the fireproof floor, the steel roof, and the iron doors and window frames, has not yet arrived, so that quite a respectable portion of the materials that are used in its erection is timber, either in its rough state for carcassing or worked up into joinery of various kinds.

With regard to the risk of fire, the danger of decomposition arising purely from damp surroundings, and the attacks of insects and vermin : we are not concerned with these at the moment, but the present chapter will be devoted to a description of the methods that should be employed in order to avoid the possibility of an attack of dry rot in a building which it is proposed to erect. That complete immunity against such a disaster can be ensured will be quite obvious from what has already been said about the life and habits of the fungus, and it is equally certain that any reasonable steps that can be taken to attain this end will be well repaid by the absence of trouble at some later date.

The four principal points that have to be taken into consideration are—the dependence of the disease on the presence of moisture for its support ; the absolute necessity for the complete stagnation of the air before it can develop to its fullest maturity ; and, to a smaller extent, the provision of a moderate degree of warmth and the total exclusion of day-light to enable it to thrive. A fifth point, of no less importance than the rest, that needs attention, is the danger of using unseasoned and infected wood in the erection of the building; this, however, cannot always be effectively guarded against. In nearly all cases of the development of dry rot, the disease originates in a position where it would be quite impossible to provide even a faint glimmer of light without going to unwise and unnecessary expense; fortunately this extravagance is not required, as by adopting suitable measures in other directions the absence of light can be neutralised without loss of safety. Warmth, while being to some extent another predisposing cause of dry rot—but only in combination with the other factors—does not require a great deal of consideration for the same reason, and as only a comparatively small degree of heat is needed to bring about the destruction of the fungus and its hyphæ, there is no reason why any serious apprehension should be felt on this score.

It can be stated, then, as a definite fact that requires special emphasis, that the predisposing cause of dry rot is the presence of dampness combined with a complete lack of effective ventilation, and that without this dry rot cannot flourish. This, however, does not necessarily mean that, given a moist and stagnant atmosphere, dry rot is bound to develop, for we have already seen that it is propagated only by means of spores, and consequently if the spores are entirely excluded, and the timber has not been in contact with the fungus, or become infected with hyphæ, no trouble of this kind can possibly arise. The danger lies in the very minute dimensions of the spores, which may be present in countless numbers without being observed, and which will lie dormant until they are deposited in a suitable position where they can germinate and develop in the ordinary way. Thus it is of the utmost importance that the conditions which are essential for successful germination should not be allowed to exist, and only thus will the danger that arises from the presence of the spore be averted, and adequate protection be afforded to the building.

Perhaps the most important consideration of any, is the provision of an unlimited supply of fresh air to the timbers that are situated in a position where they will be exposed to attack. This is nearly always beneath the ground floors, where the conditions are often such as to actually invite trouble, and it is often only by the greatest good fortune that the building escapes the attention of the disease.

The question of the supply of air must not be taken too vaguely, and it should not be construed merely into the arrangement of the building in such a manner as to *permit* the passage of air to the space beneath the floors. This could be carried out to all appearance in a most efficient manner, and yet, owing to a misunderstanding of the theory of ventilation, it might give no protection against the ravages of dry rot, as the mere provision of inlets and outlets for the air does not necessarily ensure that the air will actually pass through the openings. In certain circumstances, although every opportunity may be afforded for a through current of air, the space may actually be hardly ventilated at all, and the arrangements have little effect on the object in view. The phrase " an unlimited supply of fresh air " must be taken in a much wider sense, and it must be understood to mean, not only the provision of the required facilities, but also the certainty that such facilities are utilised as fully as possible. Thus the arrangements must be of such a nature as to produce a thorough circulation of air completely through the space, no portion being excluded from the influence of the air currents, or a danger spot will be created that may in time develop when least expected.

The common method that is employed for this purpose is the insertion of air-bricks in the external walls of the building, the inner partition walls being honeycombed, so that the perforations can work in conjunction with the air-bricks. This method is quite suitable when it is properly carried out, and, in fact, it is the only practicable way of dealing with the situation in the majority of cases. The difficulty that so often arises in this connection, however, comes probably more from a lack of thought than from actual neglect as a rule, but it is also often due to sheer ignorance of the subject of ventilation. Many people take it for granted that so long as there are two or three air-bricks in the external walls, and they are kept quite free from obstruction, nothing further is required, and that, consequently, complete protection against dry rot is afforded to the building. The air-bricks are inserted after a rule-of-thumb method, one here, another there, and the same arrangement is carried out on the opposite side of the building, without a thought as to whether they are going to be effective or the reverse. In some cases they may operate in a more or less satisfactory manner, but only too often they do not operate at all. The degree of efficiency of the ventilation can easily be ascertained by holding a lighted match to one of the air-bricks, when the strength of the air current will be plainly indicated by the movements of the flame. If no movement of any kind takes place, there is ample proof that no air current is passing either in or out.

The actual construction of the building and the insertion of the air-bricks must be considered in the light of the science of ventilation, and this side of the question should be given particular attention when the building is commenced. The science of ventilation is a most difficult subject in many of its higher aspects, and presents rather a thorny question when dealing with the space beneath the floors. It is, however, so closely bound up with the prevention of dry rot, that the natural laws which govern the movement of air currents should be thoroughly understood, and should be continually borne in mind when dealing with the matter.

Ventilation may be described as a process whereby the foul air is removed from any confined space, such as a room in a dwelling-house, and an equal quantity of fresh and pure air is introduced to take its place. On the face of it this appears to be quite a simple matter, and in living apartments, as a rule, little difficulty is experienced, as it can be accomplished by the operation of natural laws. In some cases, however, natural ventilation is not sufficient for the purpose, owing to various drawbacks which are inherent in the system, and recourse has to be made to mechanical means to enable the change of air to be effected at a suitable and constant rate. Mechanical ventilation, however, is not adapted, or even necessary, for use in the case under consideration, as the cost would be prohibitive in any but the very largest buildings, while alternative means are also available.

The efficiency of any system of natural ventilation depends entirely upon the difference in density or weight of two columns of air, and the difference in the density of the air is in turn dependent upon the operation of another force, which causes the expansion of heated matter. Thus there are two inexorable laws that are involved in any system of natural ventilation, these being the law of expansion and the law of gravitation. All materials that are employed in building construction expand on being heated, the increase in the volume being constant in each particular substance. When heated matter expands, however, its mass or weight is not increased at the same time, the increase taking place in the volume alone, consequently the object is lighter as compared with its bulk when its temperature is raised, than it was in its original state. The expansion of solids does not amount to much, in fact it only constitutes a very small proportion of the dimensions of the object, but it is sufficient to turn the scale in the balance between the same bulk of matter at different temperatures. It is this law of expansion which causes hot water to circulate through pipes to the various parts of a building, as the hot water, being lighter than cold, rises, and the colder water sinks to the bottom, forcing the hot up to the top, and thus producing a regular circulation through the flow and return pipes. Exactly the same thing would occur in the case of air, and if the air were to be confined within the limits of a pipe or tube, and heat were applied at the bottom, it would circulate in the same manner as water. In the ventilation of dwelling-houses, however, the provision of tubes would be too costly a matter, and as the air can be changed by a much simpler process, but by the operation of the same laws, it is not necessary to go to so much expense to attain the object in view.

Bearing in mind the fact that heated air, in common with other matter, expands, and therefore rises, it will easily be seen that when the temperature of a room is raised by the fire, the air follows its own natural tendency and ascends to the ceiling, while the cooler air sinks to the ground. Thus the warm air inside the building and the cooler external atmosphere may be taken to represent two separate columns of air, which, while they are at the same temperature, remain in equilibrium, but immediately the temperature of either is raised equilibrium is destroyed, and a change takes place in the respective positions of the two.

In cold weather, when a fire is in use continually, the room soon becomes warm, and if the doors and windows are kept tightly closed, the temperature continues to get warmer until ultimately it becomes oppressive. As soon as the top sash is lowered, however, the heated air escapes through the opening, and normal conditions return. But this could not occur efficiently if there were not some means of ingress provided for fresh air from outside to take its place, and as there are crevices round the door and at the lower part of the window, a continuous circulation is maintained, the colder and heavier air outside falling to the ground and entering beneath the door, and the hot air escaping through the top of the open window. A similar process occurs with the chimney, the circulation being maintained by the heat from the fire as it rises up the flue.

This brief description of the forces that are brought into operation for the efficient ventilation of living apartments, has been given to illustrate the methods that are advocated in the following pages for ventilating the space beneath the floors, and thus preventing the development of dry rot.

The principles of the ascent of heated air, as stated above, then, must be applied as nearly as possible to the ventilation of the space beneath the floors. Air-bricks alone will not necessarily induce a through current of air, but they serve the purpose of providing a means of ingress and egress, and thus they assist in the circulation of the air, so that a certain amount of discrimination must be exercised before deciding on the best position in which they can be placed.

Careful attention must be given to the positions of the air-bricks in relation to the space which they are intended to ventilate. There is very little use in placing the inlets indiscriminately along the front of the wall and fixing corresponding outlets exactly opposite on the other side. This might possibly be the means of producing currents of air between the two walls, but the currents would merely pass straight across the space, and the corners would not be affected in the least and would remain quite stagnant. It is much better that the inlets on the one wall should not be exactly opposite the outlets on the other wall; instead they should be "staggered," that is, each outlet should be placed opposite a point midway between two inlets, this method being followed all round the building, so that cross currents of air are set up. At least one air-brick should be fixed close to the angle of the room to prevent stagnant air from hanging in the corners; this is very often neglected, and as a consequence the disease develops in the angles and spreads from thence to other parts of the floor.

Economy should not be studied too closely in the provision of openings, as they are not very expensive, and it is cheaper in the long run to spend a little extra in the first place for labour and materials on this important point, than it would be to remedy the trouble after it had commenced. Plenty of air-bricks, judiciously placed, should be the principle on which the ventilation is arranged.

In very few cases, however, are the external walls of a building the only ones that need to be considered, as there are usually one or more partition walls in between to divide the building into various apartments. But this does not affect the placing of the air-bricks, as the two external walls on opposite sides are the only ones that need to be provided with inlets and outlets, and they must be treated as if the cross walls did not exist; the latter must be honeycombed, as shown in Fig. 6, when they are built. This will not only permit free movement of the air over the whole of the site, but it will reduce the cost of the wall both in labour and materials.

To make sure of obtaining the best results, it is well to view the house as a whole in order that the air-bricks can be arranged in such a manner as to induce a current of air throughout the space, all of the internal walls being honeycombed as described. It may be that some of the floors are on a rather higher level than the others, and if by good chance these particular rooms are used regularly, the heat from the fire will assist in keeping the floor and walls comparatively warm, and this in turn will raise the temperature of the air beneath to some extent. Very little difference in the temperatures is necessary to destroy the equilibrium between the internal and external atmospheres, and so to set up a movement between the two, although obviously the velocity and the continuity of the current will be in direct proportion to the variation in the temperatures and the period for which the variation exists. According to one authority on the subject, a difference of 1° Fahr. is sufficient to displace the air in a lateral direction, while to create a brisk current of air by means of a vertical shaft the variation must be as much as 30° Fahr. When the floors are all on the same level, this difference in temperature will probably operate more or less, and the circulation of air will often be accelerated by the action of the wind, but if the air appears to remain stagnant, some little assistance may be given by adopting a method of inserting the air-bricks on the leeward side of the house that is customary in some parts of the country. This is illustrated in section in Fig. 5, where the air-brick is shown to be inserted in the outer portion of the wall, about 9 ins. above the top of the opening beneath the floor, the two levels being connected by a narrow cavity that is arranged vertically in the centre of the brickwork. This method also possesses the additional advantage of preventing the air-brick from becoming choked by the accumulation of dust and leaves, so that it is quite free from obstruction all the year round. It is rather more costly to construct than the common straight-through method, but is well worth the extra expense when something a little different from the usual is required.

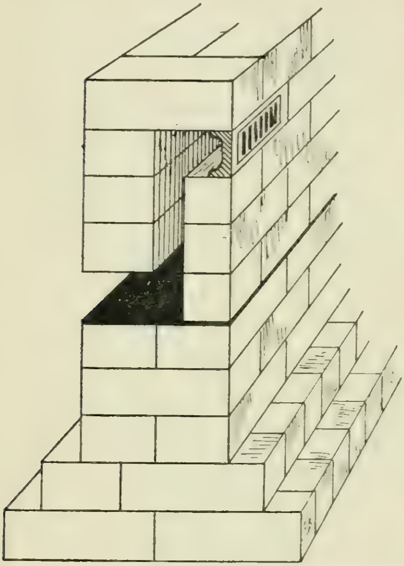

FIG. 5.—Improved Method of inserting Air-brick.

Some little benefit can also be obtained by placing the air-bricks which are on the driest and sunniest side of the house a little higher than those on the shady and possibly damp side, as this will encourage the escape of the warm air to the outside of the building. This does not affect the necessity for keeping both inlets and outlets beneath the level of the floor. On that side of the building where the joists run parallel with the wall the air-bricks must be kept below the under-edge of the timbers, those

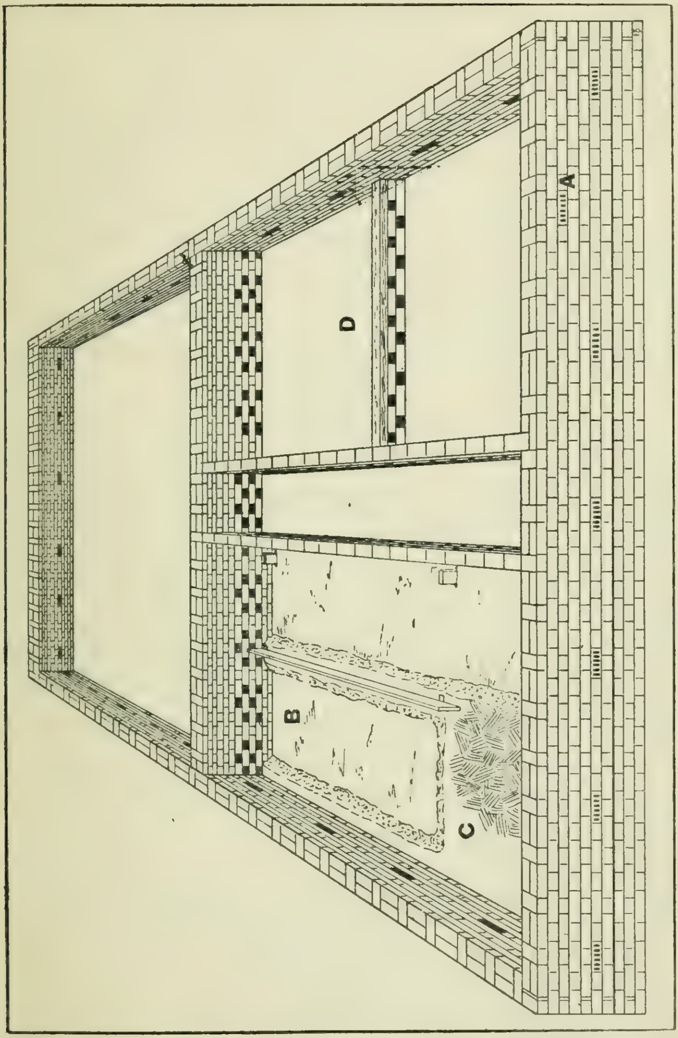

FIG. 6.—Plan of Building showing Method of Ventilation and Exclusion of Damp.

on the adjacent wall being placed a little higher, as they will be situated between the ends of the joists.

An illustration of the method of spacing the air-bricks is given in Fig. 6, those in the external walls being arranged to come between those on the opposite side. The position of an air-brick with a vertical cavity, as illustrated in Fig. 5, is shown at A. The method of honeycombing the party and the sleeper walls is also given, so that as little obstruction as possible is offered to the circulation of the air.

The ventilation having thus been provided for to the best advantage, attention can now be given to the exclusion of moisture by taking such steps as will ensure that the building shall be quite dry. Many years ago it was a common custom to lay the floors without previously concreting the site, and thus every opportunity was given for ground damp to rise, the bare earth being everywhere left exposed ; as a consequence not only dampness, but also the miasmatic vapours that emanate from decaying vegetable matter, and even the remnants of vegetation itself, could obtain access to the vacant space. This naturally produced most unhealthy conditions, and it is not at all an uncommon experience with this class of property to find that the space beneath the floor becomes flooded during an extended period of wet weather, and it is almost a foregone conclusion that rheumatics, rickets, and pulmonary disorders are quite common amongst the unfortunate occupants of such premises. Under these conditions it is only to be expected that the walls and timbers soon become saturated with moisture, and in many cases the water stands in beads on their surface. The dampness is not always so conspicuous in the summer weather, when the air is dry and perhaps little rain falls, but on a wet soil the earth practically never dries, and thus the moisture is continually being drawn upwards by the heat of the room, and the atmosphere cannot be anything but humid even at the best of times.

In modern buildings these conditions do not usually prevail, as it has now been compulsory for some years to concrete the whole site before the floors are laid. This not only keeps the moisture from rising, but it also prevents the emission of objectionable odours, especially from made-up ground, and absolutely precludes the growth of weeds and vegetable matter. Moisture is also prevented from rising up the walls by capillary attraction by the provision of effective damp-proof courses, which are placed at least 6 ins. above the surface of the ground outside, so that little danger can arise from damp walls, provided that the work has been carried out in a proper manner and with good materials. Theoretically these precautions should result in the production of a perfectly dry space, and in an overwhelming majority of cases the theory is fully borne out, as the buildings remain permanently dry. But, even supposing that these precautions are satisfactorily put into operation, there yet remains one avenue by which dampness can obtain access to the vacant space, and by which sufficient moisture for the development of dry rot is frequently conveyed to the timber. This is by the condensation of atmospheric moisture on the joists and walls, and, although it is not so constant in its recurrence as if it were the result of capillary attraction, it may often be quite serious enough to give good cause for alarm. Bad ventilation is primarily responsible for this state of things.

Condensation is brought about by the effects of yet another of the inexorable laws of Nature, and it is somewhat difficult to deal with effectively. It is quite automatic in its action, as are all of these natural forces, and at times it is responsible for quite a lot of discomfort to the occupants of the building. The method on which it operates is, very briefly, as follows :

The air in which we live always contains a certain amount of moisture in suspension, the proportion of which varies according to the existing climatic conditions ; about fourteen parts in 1,000 is usually considered to be a fair average. Warm air can support a larger quantity of moisture than cold air, the actual percentage being, within certain limits, in direct proportion to the temperature of the air at any given moment. In warm weather, when the earth has become wet after continuous rain, water is evaporated from the soil, and from seas and rivers, by the sun, and it is held in suspension in the atmosphere either as mist or in an invisible form. This evaporation continues until in time the air is so laden as to be unable to absorb any more moisture, and it is then described as " saturated." If further evaporation were to take place, it would cause the air to become over-saturated, and the moisture would then fall to the ground in the form of rain or dew.

When this stage is reached, it is called the "dew point," or the point at which the air is unable to support any further moisture and is therefore compelled to give it up as described. Now it is obvious that if the saturation point is reached at a given moment, and the temperature then falls, the air, being cooled, will not be able to sustain the burden it is already carrying, and the moisture will continue to fall until the limit of saturation has again been reached. This process is responsible for the dew which falls during the cool summer nights and mornings, when the temperature of the air drops with the disappearance of the sun.

There is, however, another combination of circumstances which often brings about very similar results from much the same causes.

When the atmosphere becomes saturated in humid weather, and it then comes into contact with a cold, impervious surface, such as painted and varnished work or metallic fittings, the temperature of the layer of air that is in actual contact with the surface automatically falls, and, the dew point being then reached, its moisture is deposited on the object in tiny beads of water. This naturally only occurs to the layer of air which is immediately adjacent to, and in contact with, the cold surface ; as, however, the air becomes heavier as soon as its temperature is reduced, it at once falls to the ground, and its place is taken by other moisture-laden air. Thus the whole process is repeated until, in time, the object becomes so wet that the globules of water, being unable to soak in, coalesce and run down to the ground in streams.

This describes the law of condensation, and it is this law which is the cause of the streaming walls and windows in dwelling-houses on warm, muggy days, and which is often mistaken for structural dampness.

The question of condensation may become of some little importance from the point of view of dry rot when humid weather prevails or, more frequently, in a water-logged district, as the damp atmosphere passes through the air-bricks into the space beneath the floors, where it comes into contact with the walls and timber, and as the temperature will probably be considerably lower than that of the outside atmosphere, the moisture is deposited on their surfaces if steps are not taken to disperse it before this can occur. Thus it is quite possible for the timber to become damp even when the precaution has been taken to concrete the site, and to provide efficient damp-proof courses.

There is really very little that can be done in circumstances such as these so far as any practical measures are concerned. The best protection against condensation is to produce such a brisk and continuous circulation of the air that it is compelled to pass through the space without depositing its watery burden, as far as this can be effected. It is not often that condensation is solely, or even primarily, responsible for the production of serious dampness beneath the floors, as the timber, being of less cold a nature than the average hard and impervious building material, does not condense the moisture to so great an extent. It may, however, operate as a contributory cause by making the walls damp, so that the moisture is evaporated into the air when drier conditions return.

When it is impossible to produce an active circulation of air by the employment of air-bricks in the usual way, more elaborate steps must be taken if absolute protection is to be ensured. A strong and permanent current of air can be promoted by constructing a shaft or flue, which, starting immediately beneath the floor, is carried up through the room above to the ceiling. The shaft is built on to the side of the chimney breast, and connects with the chimney flue at the top by means of a mica flap ventilator. This method is shown in Fig. 7, the inlet opening for the air being seen at the bottom, under the floor, and the ventilating grid communicating

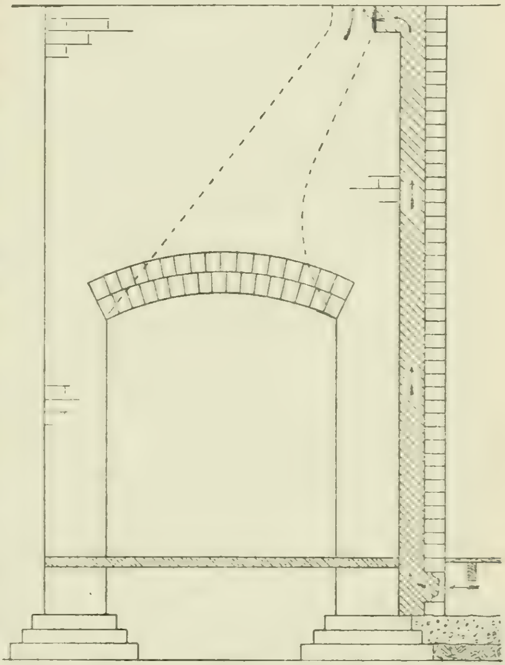

FIG. 7.—Air-shaft for Ventilation. (*The shaded portion represents the flue.*)

with the chimney at the top, the hatched portion representing the air-shaft.

The chimney that is selected should be one that is in continual use all the year round if this can be arranged ; the kitchen chimney is the most suitable for the purpose, as the fire is generally in regular use, and, the brickwork being thus kept warm, the temperature of the air in the ventilating shaft will be raised by the heat from the kitchen fire. This will cause the air to ascend on the principle that has already been explained, drawing a steady current from beneath the floor, which will in turn be replenished by a fresh supply which enters from the outside by way of the air-bricks. The ventilating grid at the top of the shaft is provided with flaps which are made out of thin sheets of mica, and these flaps are hung over the valves or openings in such a way that, while they permit the passage of air from the shaft into the flue, the air current cannot be reversed in the event of down-draught ; thus the possibility of smoke or sparks being blown back down the shaft is obviated. The practice of connecting separate shafts with a chimney flue is not generally recommended, as it is apt to interfere with the proper working of the chimney itself. The only method by which this can be avoided in the present case is to continue the air-shaft up through the roof to the top of the chimney stack, where it is allowed to discharge into the open air ; by this method no connection is made with the flue, which is therefore not interfered with in any way.

The air-bricks must be placed with careful consideration of their relation to the shaft, so that the current of air, which passes in a straight line from one to the other, will thoroughly ventilate all the corners and angles throughout the building. The whole space will then have a complete and constant change of air, and there will be little encouragement for dry rot to develop in any part of the building. This method is rather expensive, but when working properly it will constitute a most efficient ventilating system, and great benefit will be derived from its introduction.

With the ordinary method of building construction it is rather a difficult matter to ventilate the spaces between the joists on an upper floor, as each space is quite separate from those on either side, and such a large number of air-bricks would be required that they would be much too conspicuous a feature in the elevation of the building. Dry rot does not attack the upper floors very often, however, as they do not usually suffer from dampness, but as the use of unseasoned or infected timber may give rise to future trouble, it may be considered a wise precaution to create a draught between the boards and the plastered ceiling, in order to prevent the germination of any dormant spores that may be concealed in the timber. A few air-bricks, situated here and there round the wall, a little below the floor boards, in a similar manner to those that have been inserted below, will be of some assistance in this direction without appearing very prominent, while the spaces between the joists can be connected by boring a number of holes through each one, the holes being placed exactly on the neutral axis of the joist, so that its strength is not materially reduced. The space can also be connected to an air-shaft where such facilities are available, an opening being cut in the side of the shaft for the purpose. An alternative, and much more effective, method would be to introduce a string-course of ornamental perforated bricks along both of the outer walls immediately opposite the ends of the joists.

Dry rot very frequently develops in the ends of purlines or joists that are built into the brickwork, as the air is entirely excluded from the wood, and the moisture from the damp mortar is absorbed and retained in its cavities. The practice of bricking the ends in closely is very common, but it should be avoided, at any rate as far as large and important timbers are concerned, as a great deal of damage would in all probability be caused by the failure of the beam.

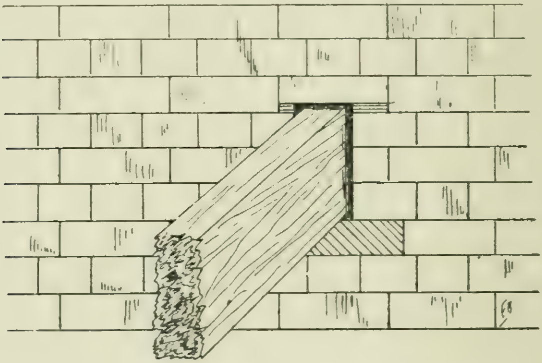

FIG. 8.—Air Pocket round End of Beam.

When it is necessary for any weight-carrying timber to take a bearing in a wall, a pocket should be built in the masonry for the reception of the end, similar to that shown in Fig. 8, so that a space of 1 in. is left all round the sides and top of the timber for the circulation of air. As timber always gives up its contained moisture more freely at the end grain than at the sides, the pocket should be deep enough to allow the space to continue round the end, as well as the sides, so that any moisture can evaporate without hindrance. It is most important that this precaution should be observed in the case of large timbers supporting floors, the tie beams of roof principals, etc., the ends of the beams resting on York stone templates, so that the superimposed weight is distributed over a suitable area of brickwork.

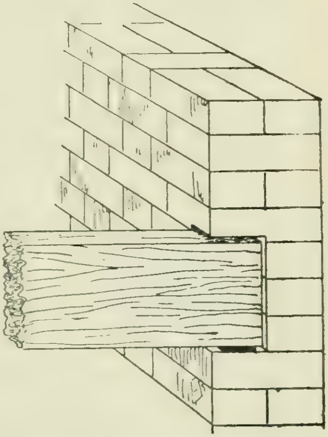

FIG. 9.—Iron Bar in place of Wood Plate.

Bond timbers and wall plates that are built into the wall also frequently fall victims to dry rot, for the same reason as that just described. It is much the better plan to dispense altogether with wood and to employ a bar of 2½ ins. by ⅜ in. iron for the plate, as illustrated in Fig. 9. This is often done in the best work, and disposes of the liability to decay without difficulty.

It is not altogether an uncommon occurrence for wood block floors to be attacked by dry rot, this being mainly due to inferior workmanship in the first place. When this type of floor is employed, the blocks should be laid in mastic on an impervious foundation, the concrete which covers the site being finished off with a ¾ in. rendering of waterproofed cement mortar. This will effectually prevent moisture from rising upwards from the soil below, and will produce an environment that is unfavourable to the germination of the spore. In a badly constructed floor the concrete may be of poor quality, and the rendering weak, consequently there is nothing to stop the moisture from rising, and as there are no means by which air can circulate round the bottom and sides of the blocks, a certain element of risk exists, which may develop as time goes on. Floor boards that are nailed directly on to breeze concrete should have the edges and the under-sides creosoted before they are laid, and the surface of the concrete should be thoroughly well tarred. There is some little objection to the use of tar or creosote in dwelling-houses owing to their pungent smell, but the odour, especially that of creosote, soon dies away, and is not noticed after a short time.

It has been suggested at times that none of the floors, skirtings, panelling, or other woodwork in a building should be fixed until the walls have had sufficient time to dry out. This, no doubt, would be advisable, but it is a policy of perfection that would be quite impossible under the present-day conditions of rush and hustle, although it cannot be disputed that it would save a good deal of future trouble and expense in various ways if it were practicable. As a general rule, however, the most that can be done in this direction is to allow as long a period as possible to elapse after the roof has been covered in before proceeding with the fixing, so that a part, at least, of the moisture can be evaporated before the walls are covered up.

Floor boards should not be cut to fit tightly against the brickwork, as this will create a stagnant atmosphere behind the skirtings. If the boards are cut so that a space of ½ in. is left all round the room, it will provide a means for the air to circulate behind the skirting and panelling with good effect. Tongued and grooved floor boards also tend to prevent the change of air between the joists of upper floors ; square-edged boards would not have this effect.

A rather less common cause of dry rot in buildings is the practice of using lime mortar for pugging between the joists to prevent the passage of sound between the various rooms. It is obvious that the mortar will prevent the access of air to the joists, and, owing to its alkaline nature, it is very apt to encourage the trouble. This is the more serious as pugging is only used on upper floors, where the difficulties of ventilating the space are somewhat acute. The best method of avoiding this, when pugging is essential, is to employ a loose material such as silicate cotton—commonly called slag wool—which not only prevents the passage of noises, but also permits the air to circulate to the timber, and which does not contain any alkali to encourage the growth of the fungus. Cabot's Quilt is also very suitable as an insulating material for this purpose.

The danger of dry rot is considerably aggravated by the practice of covering the floors with linoleum and other types of impervious coverings. This has the effect of preventing the passage of air through the joints between the floor boards, and assists in confining the air to the space below the floor. Thus a very valuable means by which the floor can " breathe " is entirely neutralised, and the opportunities for dry rot to develop are increased. Many property owners stipulate that the tenants of their houses shall not use linoleum as a covering for wood floors, in order to avert the possibility of danger in this respect, and although the stipulation appears to be somewhat drastic, yet it can fairly be argued that the end justifies the means.

If it is particularly desired to employ a floor covering that is impervious to the air, it should not be laid completely over the floor, but a margin should be left all round the edge, extending for at least a foot from the skirting ; the bare boards can be stained and varnished, and the margin will not then be very conspicuous. This will make it possible for a portion, at any rate, of the air below to be drawn up into the room through the joints by the action of the chimney, and will tend to prevent complete stagnation beneath the floor. The fact that the air is drawn into the room in this manner emphasises the importance of keeping the space dry and free from decaying organic matter.

Dry rot will also frequently develop between the top of the boards and the linoleum, owing to the absence of fresh air. This is an additional argument against the use of impervious floor coverings.

Before the floor boards are laid the surface of the concrete which covers the site should be swept clean, all *débris* being removed and carted away. It is particularly desirable that any chips or shavings that may have been left by the carpenter should be removed, as each one of these may be a carrier of disease that might in time be communicated to the floor timbers. It must be remembered that it is not only the germination of the spore that has to be guarded against ; the smallest piece of hyphæ that may be hidden in the interior possesses great vitality, and will commence to grow and spread as soon as the conditions are favourable. This will indicate the extreme danger that exists if the timber has been in contact with other infected material.

The subjection of the timber to a preservative treatment by the antiseptic process before it is fixed is often advocated as a means of preventing dry rot, creosote being one of the most favoured mediums for the purpose. This is a distinctly good method, provided that it is carried out properly. The creosote, on being injected into the timber, coagulates the albumen in the cells so that it is not so liable to decompose, and itself solidifies, choking the pores and making the timber more or less impervious to moisture, while at the same time it leaves a certain amount of carbolic acid in the cavities. If the timber is thoroughly dry before treatment, this will be quite satisfactory, as even in the event of a spore germinating—which would be very doubtful under the circumstances—the hyphæ would be unable to penetrate beneath the surface of the timber, and it would die either as the effect of the fungicide or from want of nourishment. If, however, the timber is wet, the closing of the external pores when the creosote solidifies merely prevents the evaporation of its moisture content, and as it may quite possibly contain spores or hyphæ in the interior, only one result can ensue. Thorough seasoning destroys the hyphæ, and goes far towards sterilising the spore. In the Powell Wood-Process method of treatment, a saccharine solution—generally in the form of molasses—is employed as a preservative medium, and the system has attained a large measure of success in tropical countries, where the raw material from which the solution is prepared is less expensive than it is in the home market.

With regard to the sapwood, it must be noted that this is the most suitable portion of the timber for the propagation of the disease, but once the spore has germinated and developed, the hyphæ will spread far beyond its original base, and the heartwood is soon involved in the general ruin. Sapwood, however, does not necessarily decay when it is used in a dry situation, provided that it is kept permanently dry. The sapwood of Scandinavian timber has been known to remain in a perfectly sound condition for as long as 150 years. Sapwood cannot always be readily distinguished in fir timber, as its colour does not vary greatly from that of the true wood. After exposure to wet, however, the sap in converted timber generally turns to a dirty green or blue colour, when it can easily be distinguished from the heartwood.

Another very effective safeguard for preventing the development of dry rot is to make sure that no damp or unseasoned timber is employed, as by this means a great deal of the risk that would otherwise be incurred is avoided at the commencement.

From the time when the tree is felled to the time when the timber is used for structural operations quite a number of processes have to be gone through. Taking the case of English oak, the tree is usually left lying on the ground for a year after it has been felled, the bark being removed in some cases, while in others it is left on. Stripped oak is of slightly inferior quality as compared with winter-felled oak, as the tree has to be left standing until the sap is up before it is thrown, or it would be impossible to strip the bark off without so much trouble that it would not be a paying proposition. The presence of the sap in this class of timber makes it less durable. After lying on the ground for some time the butt has to be transported to the sawmill either by road or rail, and it is then converted into various thicknesses of plank, according to the purpose for which it is intended. Some little time is allowed for the timber to season, one year for each inch in the thickness of the plank being usually considered sufficient for air-drying, and it is then shipped to its destination, after passing through various hands before it reaches its ultimate purchaser. During the seasoning period it is supposed to stand in the stack for a sufficient time to allow the timber to dry thoroughly, but this process is very often a much shorter one than is advisable, so that the condition of the timber is not all that could be desired. A good deal of the timber that is on the market at the present time is very inferior in quality, and can only be described as rubbish, but owing to the excessively high prices that rule to-day, it is sometimes employed for work where it would not have been tolerated twenty years ago. This refers especially to the soft-wooded varieties. The average grade of timber contains rather a large proportion of sapwood, and this sap may be a potential and fertile source of trouble in the future so far as dry rot is concerned, as it furnishes the very nourishment that the fungus requires for its subsistence. In sound wood of good quality that has been thoroughly seasoned, the cell contents are dried up or dissolved according to the method that has been adopted for bringing it into condition, so that there is less likelihood of anything untoward occurring in this respect.

During the operations that take place after the tree has been felled ample opportunities are afforded for spores to effect a lodgment in the crevices of the timber. This may occur in the forest, where it is open to the attack of *Polyporus vaporarius* and other species of fungus ; in the sawmill, where it may come into contact with other infected timber ; or in the timber yard, while it is standing in the stack. Timber yards are sometimes infested with dry rot, owing to very culpable carelessness in protecting the stacks from the creeping hyphæ or in guarding against the dissemination of spores. This probably accounts for many attacks of dry rot that would otherwise remain more or less of a mystery. Sometimes the spores may remain dormant in the timber for a time, and may only break into life after the building in which it is used has been completed. Under more favourable conditions, however, the spore may germinate in the timber yard, and may spread through the stack, so that, while the timber may appear to all intents and purposes to be quite sound, yet the hyphæ may have penetrated to the interior and be only waiting to commence operations. Thus the importance of using only dry timber that is free from sap cannot be ignored, especially for floors and in other situations that are likely to breed disease. All timber that may have been infected in the yard should be sterilised before being sent away. This can be done by subjecting it to heat either in a drying kiln that is raised to a temperature of about 110° Fahr., or by steaming. No harm will be done to the timber by this treatment, provided that the temperature to which it is subjected does not exceed 200° Fahr. As a reasonable precautionary measure, however, timber yards that are known, or that are even suspected, of being infected, should be avoided as the plague for reasons that are only too obvious.

It will be recognised that it is essential to observe a good many conditions before positive and permanent immunity from dry rot in the future can be ensured, but the trouble that is involved is well worth while if by this means the dread disease can be averted. The most important points to be considered and provided for are undoubtedly the prevention of dampness, and the production of a free and complete circulation of air, and if both of these essential conditions can be complied with, there will be less need to go to any undue trouble with the remaining details. Only those whose unfortunate lot it has been to experience the destruction that can be wrought in such a short time by a bad attack of dry rot, can really appreciate the immense importance that attaches to the employment of every available means for avoiding such a disastrous calamity.

Fig. 10 illustrates the serious consequences that are certain to ensue if the development of dry rot is neglected. The complete destruction of the timber is admirably shown in the figure, which provides a very graphic warning as to the supreme necessity for taking immediate steps to avert the danger that would otherwise be bound to arise.

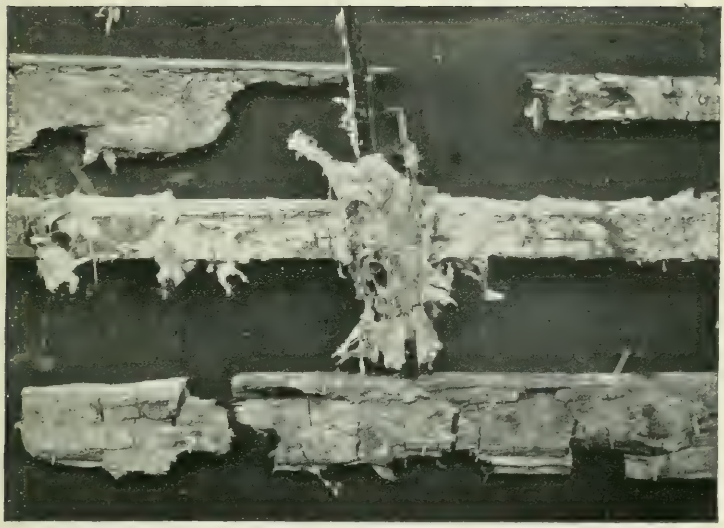

FIG. 10.—Timber destroyed by Dry Rot.
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CHAPTER IV

THE ERADICATION OF DRY ROT FROM OLD BUILDINGS

THE eradication of dry rot from a building where it has once obtained a fair start is a very different proposition from the prevention of its development when the building is erected, and very different measures are required for dealing with the situation. In one respect both cases are alike, that is, in the meticulous care and thoroughness with which any measures that are adopted must be carried out. If it is at all possible to err on the side of thoroughness, the error should be committed when taking remedial, as distinct from preventive, measures. It is a comparatively simple matter to take such precautions as will ensure that the chances of the development of the disease shall be of the most slender nature, but with an existing attack the burrowing propensities of the hyphæ make it quite impossible to guarantee that none of the timbers are permeated with at least a small portion of the roots. If these are left in, the trouble and expense may quite possibly be wasted, and the whole procedure may have to be gone through a second time.

Dry rot is found in old buildings much more frequently than in new ones, for reasons that have already been explained. To make matters worse, the disease is very much more difficult to deal with in property that has seen its best days, as the age and general condition of the structure lend themselves to the rapid development of the mycelium, and present increased difficulties when taking steps for its eradication.

New houses, however, frequently give rise to a good deal of apprehension as to the possibility of attack, as the quality of the timber that has been used in their erection is often inferior, while it is not at all unlikely that one or more of the precautions that are essential to safety may either have been omitted, or else carried out in such a slipshod manner that they are practically useless as a protection to the building. In either case the most drastic steps must be taken before a cure can be even provisionally guaranteed, and the slightest laxity either in the methods that are adopted or in their practical application, may be fraught with the most serious consequences at some later date. Any of the species of dry rot that have been mentioned may be found at times, and the attack may be serious or the reverse, according to the progress which the disease has made, but in any case it is serious enough to demand that the most instant and thorough treatment should be put in hand, or the difficulty will increase in a very short time.

While it has been observed that *Merulius lachrymans* is the commonest and the most malignant of the three principal varieties of dry rot that are found in this country, the measures which are described in the following pages are capable of destroying both the fungus and the spores of this and of the less deadly species, and to give reasonable assurance that no further trouble will be experienced.

With old property that is in the last stage of disrepair the question will naturally arise, " Is it worth while to go to so much trouble and expense, when the condition and the probable life of the structure are taken into consideration ? " The matter must, of course, be decided on its own merits, and on the circumstances which exist at the time, but there are undoubtedly a large number of old houses, especially in country districts, which are so dilapidated that they would not justify the rather heavy expenditure that would be entailed before the object in view could be accomplished, for any but sentimental reasons.

It is always advisable when dealing with this class of property to assume the possibility, if not the probability, of the existence of dry rot, and to keep a very careful watch for any indications of its presence that may appear. In many cases the first symptom that is noticed is when the floor boards give way under some extra pressure that is placed on a weak spot, or perhaps the floor covering begins to show a suspicious unevenness in the corners of the room. By the time these signs become apparent, however, the disease will have made considerable progress, and the indications are that the matter has been neglected for too long a time. A case somewhat similar to this occurred in Yorkshire, in which the writer was called in to advise as to the steps that were required for dealing with the collapse of the floor in one of the rooms. In this instance the disease was so firmly established in the ground floor timbers, and had evidently been allowed to continue unchecked for so long a time, that the joists and sleepers had at last given way, and quite a large area of the flooring had to be entirely reconstructed before the trouble could be surmounted. Earlier attention would have reduced the seriousness of the attack considerably, but it was a very old house, and the signs had either been misconstrued or entirely overlooked. It is unfortunate, however, that in some cases the joists may be more seriously affected than the floor boards, so that quite a lot of damage may be done before any signs of the disease can be detected. Hence, in old buildings it would be advisable to examine the floors from time to time, by lifting a board in the corners of the room and making a thorough inspection of the space beneath with the aid of a portable electric lamp.

The first superficial evidence that will be observed as a rule is the discoloration of the floor boards, which may turn of a rusty brown hue, or they may become discoloured by red or brown streaks. If this is allowed to persist, the boards will show signs of shrinkage; short cracks will appear, as in Fig. 4, and the surface is easily rubbed up by contact with the legs of chairs and tables, or merely by the passage of ordinary foot traffic. A closer examination will reveal that the wood is soft and has lost all its nature, and that it can be picked to pieces with ease, while the fragments can be crushed to powder between the fingers. Sometimes the indications may appear chiefly in the skirting or panelling, but these when painted conceal the trouble for some time. Cracks, however, cannot be hidden for long, and ultimately they will show through the paint. When cracks appear, especially across the grain, the trouble can generally be diagnosed as dry rot, and a further investigation will probably put the matter beyond doubt, so that no further hesitation can be needed as to the situation that has to be coped with.

When dealing with an attack of dry rot, two main objects must be held in view, and neither must be lost sight of for a moment. These are obviously the total destruction of the fungus and its spores and, what is no less important, the prevention of a recurrence of the disease. Preventive measures have already been dealt with in the previous chapter, and it thus remains to consider the best method by which the entire and permanent destruction of the pest can be achieved, always remembering that it is of a highly infectious nature.

As a preliminary the whole of the infected floor boards must be taken up, thus exposing the joists and sleepers below. When this has been done, a much better idea of the extent of the trouble can be obtained, as the network of roots and the masses of mycelium can then be seen without difficulty. The area of floor that must be removed will be determined by the distance to which the roots have travelled, each one being traced to the farthest point at which it is visible. The boards must be cut away to some little distance beyond this point, as, although the hyphæ may not be seen on the surface, they may still be present in the interior of the timber, where they will be equally, or even more dangerous, than if they were in full view on the exterior. All the boards, joists, and sleepers must be cleared out without hesitation for not less than 4 ft. beyond the extreme limits of the disease, to ensure, as far as possible, that nothing but sound, healthy timber is left in the room. Skirting and panelling that may have been infected must also be relentlessly condemned. This part of the operation must be carried out very thoroughly, and if any fructifications are discovered, they must be removed with great care, placed in a pail, and covered up, so that none of the spores that may be attached to the surface can escape, to be distributed in other parts of the house. Not the least scrap of timber must be left in place, even though it may be to all appearance quite sound and free from disease ; it has been in contact with other infected timber, and therefore it is not safe to be left. Every wood block and plug that may have been driven or built into the wall for fixing the joinery must be taken out with the same care and thoroughness. All infected timber must then be carried out of the house by the shortest route and burnt in the open air away from any adjacent building until it is consumed. This precaution is necessary, as the possibility of spreading the infection to some other structure is dangerously real.

The next step will be to scrub the wall down all round beneath the floor with a stiff, scrubby brush, to remove any hyphæ or spores that may be adhering to the brickwork. The crevices must be well brushed out, as they are almost sure to contain pieces of roots, which will be certain to spring into life again if they are not destroyed. The holes that have been left by the removal of the blocks can be cleared out with a trowel or a piece of wood.

Very few of the older residences will be found to have the soil concreted beneath the floor, as this was not usually considered to be necessary at the time of erection ; thus every opportunity is provided for the damp to rise and to produce ideal conditions for dry rot. The earth is sometimes very wet beneath these old buildings, especially in low-lying parts of the country, where the natural contour of the ground does not encourage the escape of surface water. In any case, when the mycelium of dry rot has fructified, and the spores have ripened and fallen off, they are bound to be present in millions in the surface of the soil, and they will probably be accompanied by numbers of hyphæ which, encouraged by the moisture, have spread from the timber and penetrated into the earth. To get rid of these potential sources of trouble, a depth of 3 ins. must be taken off the top soil all over the affected room and carted away to be burnt in the same manner as the timber, or spread over the ground.

When these measures have been carried out with close attention to detail, all traces of dry rot will have been removed so far as can be seen. These measures, however, are not sufficient for the purpose in view, and would not be of the least use as a cure by themselves, as numbers of spores may still be left to carry on the work of destruction if they are not rendered incapable of further mischief. They can, and must, be destroyed by the application of a powerful disinfectant to the whole of the space that is being dealt with. The walls, floor, and the surface of any adjacent timber that is, or can be made, accessible by any means must be treated in turn with the very greatest care.

A liquid disinfectant is the most convenient, as it can be spread easily and expeditiously, and will penetrate into all the cracks and corners that may need attention. The strongest and most effective liquid that can be used is a dilute solution of bichloride of mercury (*corrosive sublimate*). This must be handled with extreme care, and when not in use should be kept permanently under lock and key, owing to its highly corrosive and poisonous nature.

Another disinfectant which is guaranteed to destroy all forms of vegetable life is Calvert's No. 5 carbolic. This must be diluted with water, in accordance with the instructions on the tin in which it is packed.

The solution must be brushed over the whole of the exposed surfaces without exception. It must be applied liberally, so that it can soak into the surface, and must be worked well into any crevices and awkward places that may exist. A second coat should be applied when the first has dried, equal care being taken with the spreading, so that none is missed. The liquid can best be distributed over the soil with a spray, and if a suitable apparatus is available, the walls can also be treated in the same manner instead of with a brush. Spraying apparatus is not always at hand, however, so that the operation must be carried out by the more primitive method. When there are deep holes and crevices in the walls which cannot be reached by the brush, a more effective treatment should be adopted by burning them out with a blow-lamp, the flame being allowed to play on the place long enough to destroy any life that may be concealed within. It can then be taken for granted that every trace of the disease has been eradicated, and steps can be commenced to reinstate the woodwork and to provide against any recurrence of the trouble.

It must not be supposed, however, that treatment with a disinfecting solution ensures permanent protection against any further attack of dry rot. This is not so, as the solutions evaporate in time and thus lose their efficacy. Their purpose is the destruction of any traces of the disease that may be within reach, and this purpose is admirably fulfilled. Any hyphæ that may be in the interior of the timber are obviously out of reach of a liquid disinfectant, unless it is injected under pressure or by soaking, so that the importance of removing any wood that may harbour spores or hyphæ can be realised.

Before the replacement of the floor is commenced the site must be concreted for the purpose of preventing moisture rising from the ground. The concrete should be as dense as possible, and should be composed of six parts of gravel to pass a 1½ in. ring, three parts of sharp sand, and one part of Portland cement, all by measure. The gravel must be spread out on a clean, hard floor, covered with the sand and cement in alternate layers, and then turned over with the shovel at least twice dry, and then twice more while it is being wetted. This will ensure the proper mixing of the matrix with the aggregate, which is most essential. The concrete should be mixed in such quantities at a time that it can be deposited in its place before the initial set takes place, the actual quantity being dependent on the amount of labour that is available. Three men can usually deal with 1 cubic yard of gravel and the necessary sand and cement at each operation. The mixture should not be made so wet as to be sloppy, but just sufficient water should be added to moisten every particle of the ingredients.

Before depositing the concrete the site should be prepared by driving a wooden peg into the ground at one corner of the room, the peg projecting from the earth 4 ins. Other pegs should also be driven in along the side of the wall, at intervals of 8 ft. or 10 ft., each one being levelled from the preceding one with a straight-edge. This procedure must be carried out at both sides of the room, and another row of pegs should also be set up in the centre, so that the rows are not more than 10 ft. apart. If any of the pegs project less than 4 ins. when they are all levelled, more soil must be removed from its vicinity, as the top of the pegs represents the surface of the finished work. Four inches is the least thickness that is permissible. The concrete is then deposited in bands or screeds, as shown at B in Fig. 6, the height being determined by placing the straight-edge on two adjacent pegs and gently smoothing the top of the concrete with a shovel until it is perfectly straight. In the illustration, the first screed is shown complete along the side of the left-hand wall, while in the centre one the concrete has been roughly deposited and is being levelled off with the straight-edge, which is seen resting on two of the pegs. The concrete must be worked well into the corners of the brickwork by chopping it with the shovel, so that there is no possibility of pockets or vacant spaces occurring. The screeds when completed must be allowed to harden before any further progress is made with the work ; it is much the better plan to suspend operations until the next day. All the pegs must be withdrawn at this stage, the holes being filled up with cement mortar. This precaution must not be omitted, or direct contact with the soil below will be established, and when the pegs decay in course of time, a convenient channel by which moisture can rise from the ground will be produced.

The screeds will be hard enough to bear walking on without injury on the following day, and the spaces between can then be filled in with concrete, the top of which is levelled off by resting the end of the straight-edge on the screeds in the same way as it was rested on the pegs in the first case. Care must be observed when depositing the concrete to make it as dense as possible by working it about repeatedly and patting it sharply with the back of the shovel. It should not be made too smooth on the top, and can be brushed over with an old stubby broom with advantage, to roughen it, and thus to provide a key for the subsequent rendering coat of mortar. In Fig. 6 a portion of the first bay is shown filled in with concrete at C, the broom marks being seen in the middle of the bay. In practical work the screeds would be all laid in before the bays are commenced.

The rendering coat of waterproofed cement mortar is not absolutely essential, provided that the concrete has been finished off quite level and is thoroughly dense and solid. Still it makes a much better and safer job, as any stray roots or spores that may still be living in the soil are more likely to be prevented from making their way through to the floor.

The mortar should be spread over the top of the concrete to a thickness of $\frac{3}{4}$ in. as soon as the latter is hard enough. The concrete should not be allowed to become quite dry before this is done, or the adhesion between the two will be weakened or altogether destroyed. If it has become dust-dry, the surface must be well wetted before resuming operations. Cement mortar can be made waterproof by correct proportioning and very careful mixing, but the extra time that is involved in its preparation and deposition is hardly worth while when the same object can be achieved more effectually at little additional expense for material, by adding a very small proportion of some reliable waterproofing compound to the cement before it is mixed. There are many kinds of integral waterproofers on the market in either powder, paste, or liquid forms, the former being the easiest to handle, and being preferable of the three. The mortar should be gauged four parts of sharp washed sand to one part of Portland cement by measure, the percentage of waterproofer that is employed being in accordance with the instructions that are issued by the makers. Very thorough mixing is essential in this case as well as with the concrete, and even more care must be observed not to use any of the mortar after it has set, as it is then more or less inert and is useless for the purpose for which it is intended.

The method of spreading the mortar follows on the same lines as those described for depositing the concrete. No pegs are needed in this case, but small blocks of wood, $\frac{3}{4}$ in. thick, can be laid on the concrete at intervals instead, if desired, as a guide to regulate the thickness of the screeds, the blocks being afterwards removed and the holes filled up. The screeds are laid down the sides and centre of the room as before, and the intermediate bays are filled in and levelled off with the straight-edge in the same manner. It should be noted, however, that if all the rendering cannot be completed in one day, the raw edge of the mortar that is left at night should be splayed off to a feather edge about 4 ins. long, and should be painted with a thick slurry of cement and water before recommencing work in the morning. As a general rule, this will hardly be necessary when dealing with the floors of a dwelling-house, as the superficial area of the rooms will not be so large as to occupy more than one day for covering them in. No specially smooth finish is required to the rendering, provided that the mortar is worked into intimate contact with the concrete, and that it is pressed well into the angles of the brickwork and floor.

In a good many cases—perhaps the majority—the walls will be in a very damp condition, owing to the absence or the failure of the damp-proof course. This must be remedied by rendering the walls over with

$\frac{3}{4}$ in. of waterproofed cement mortar from the floor level down to the concrete, the rendering being joined to that on the floor, so that a continuous lining is provided between the two. Thus the floor timbers will be situated in a cement-lined waterproof space, that will entirely prevent the entrance of moisture from the wettest ground.

These measures will make the best possible job, and one that is absolutely damp-proof. They are rather expensive, and on a dry soil the rendering could be omitted, but the concrete is essential and should be carried out with greater care.

Before going any further it will be necessary to attend to the air-bricks on the lines shown in Fig. 6, and they must be inserted at frequent intervals all round the walls. The remarks on the method of fixing and with regard to the relative position of the air-bricks in Chapter III. apply here also, and every effort should be made to create as brisk a circulation of air as possible from end to end of the building. In exceptionally obstinate cases of sluggish draught it will not be difficult to run an air-shaft up by the side of the chimney breast, as shown in Fig. 7, although this will naturally be avoided if it is not absolutely essential, on the score of expense. In this case the position of the air-bricks will be governed by the position of the air-shaft, and they must be placed so that the current of air from each one will have an unobstructed passage to the shaft, and thus every part of the floor will be ventilated. When the partition walls are solid, openings can be made for the air currents by cutting out bricks at intervals as required, as this will not endanger the stability of the walls, provided that not more than one brick is removed at a time. Too many openings cannot be made so far as the ventilation is concerned.

If the old joists were fixed to a plate built into the wall—as they often were years ago—the plate must be removed bodily and the space filled up with fresh bricks after it has been thoroughly disinfected or burnt out. Bond timbers also must be removed and made good in a similar manner ; where they provide necessary support to the building, their place can be taken by a 2 in. by $\frac{3}{8}$ in. flat iron bar, which is built into the opening with bricks and cement mortar in such a manner as to take up any tensile stress that may be developed, the ends of the bar being caulked for the purpose. No timber of any kind must be left, as even if it were covered with cement rendering the possibility of the spread of hyphæ through the brickwork would still exist, and it might be an active source of trouble if allowed to remain. Beams that are built into the wall to carry the roof or floor, and which will obviously be difficult to remove, can, if their condition warrants, have the surrounding brickwork cut away from the ends, a pocket being formed for the circulation of the air, as illustrated in Fig. 8. Should the beam have already been slightly attacked by dry rot, the decayed portion of the surface should be scraped off and the remainder thoroughly saturated with the disinfectant, so that the hyphæ will be destroyed. This is the best that can be done under such circumstances, but a careful watch must be kept for any further appearance of the disease. As an additional precaution it would be advisable to insert an air-brick in the wall immediately opposite the end of the beam ; this will be the best protection if it can be arranged. Sometimes the complete renewal of the beam can be avoided by building a stone corbel into the wall under the end, for its support, the corbel projecting about 4 ins. to 6 ins. from the brickwork.

The particular care that should be observed in the selection of the timbers for replacing the floor has already been pointed out. The greatest danger lies in the introduction of unseasoned timber to a damp and badly ventilated situation, and even when ideal conditions have been produced by the adoption of suitable measures, it is better to be on the safe side and to reject all timber that does not comply with the requisite conditions. The difficulty that is so often encountered in this respect lies in the fact that timber of the best quality is not always readily procurable, and that much of even the brightest and clearest grades of deal has quite a large proportion of sap, and this, owing to its light colour, is not always easily distinguished from the heartwood. When the best timber that can reasonably be obtained cannot be altogether relied upon, it should be disinfected before it is built into place, or it can be treated with one of the many preservatives that are on the market. In any case it is advisable to take the precaution of saturating the ends of the timbers with the disinfectant, allowing the liquid to soak into the grain as far as time will allow.

It should not be forgotten, however, that a superficial application of any kind of solution, no matter how effective it may be as a disinfectant, will not be able to reach and destroy the hyphæ that may have burrowed into the interior of the wood, and if the least trace of even a single living hypha is left, it will develop and spread as soon as the opportunity arises.

Then there is another important point that will bear repeating. All tools, such as saws, hammers, chisels, shovels, etc., that have been employed for the removal of the fungus-infested timbers, must be taken right away from the house and thoroughly cleansed by immersion in a bath of disinfectant. If this is neglected, it is quite probable that some at least of the spores will be deposited on the new timber, and the consequences may be serious.

The reinstatement of the floor and skirting can be taken in hand as soon as the cement rendering has dried. The work will be carried out in the usual way, 4½ in. sleeper walls being built across the room at intervals of 6 ft. or 8 ft., with plates bedded on top to which the joists are nailed. Some authorities contend that it is unwise to bed the sleepers with mortar, as no air can get to the bottomof the timber, and dry rot is thus encouraged. There is a good deal of truth in this view, and the sleepers can be laid dry on the walls as an additional safeguard. The sleeper walls must be honeycombed from end to end, as shown at D in Fig. 6, by setting each brick 4½ ins. away from its neighbour instead of keeping them close together. None of the timbers must have their ends touching the brickwork, but they must be cut 2 ins. short, so that a clear space will be left at either end. A space of $\frac{1}{2}$ in. should also be left between the wall and the edges of the floor boards ; air can then circulate at the back of the skirting and panelling with good effect.

The method that is sometimes followed of continuing the wall plaster down to the floor and fixing the skirting back close to its surface is not altogether advisable from the point of view of dry rot, as it leaves no room for the air to get to the back. The best method is to fix wood plaster grounds and blocking pieces, or " soldiers," and to nail the skirting to these after the plaster is dry. Breeze bricks are preferable to wood plugs for fixing joinery work, as they provide a good hold for the nails and are not likely to disintegrate or decay. When the walls are panelled, the top edge of the skirting is usually nailed back close against the bottom rail, and a continuous space exists behind the two ; if a few 1 in. holes are bored through the top rail of the panelling, equidistant from each other, a current of air will be induced to rise from beneath the floor and escape into the room, and a regular circulation will be maintained. The holes can be covered with metallic gauze, which is held in place by a brass card frame, screwed on the front. This will not appear unsightly.

In a good many of the older houses, and also in some of the new ones, the kitchen has a solid floor, which is covered with stone flags or wood blocks. This type of floor makes it impossible to follow the usual method of inserting air-bricks in the external wall of the room, and will thus militate to some extent against the complete ventilation of the floors, so that one corner of the building at least will be obliged to remain more or less stagnant. This, of course, would not do ; but the difficulty can easily be surmounted by cutting a hole in the wall between the solid floor and the room adjoining and laying a row of ordinary drain-pipes in the ground under the stone flags, the pipes connecting the hole with an air-brick that is fixed in the external wall of the building in the same way as the others. This is shown in section in Fig. 11. The sectional area of the bore of the pipes must be at least equal to the openings in the air-brick. This is rather an expensive method, but in many cases the need for an outlet at the side of the building is imperative, and it can therefore hardly be avoided. Another method, which costs very much less, although it is at the sacrifice of a part

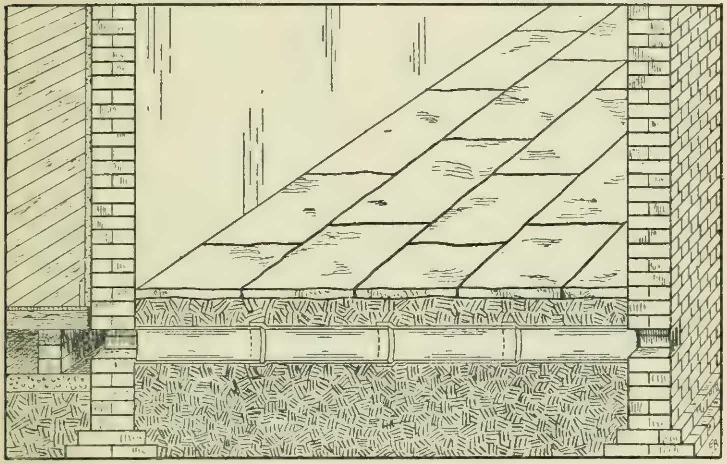

FIG. 11.—Method of Ventilation beneath Solid Floor.

of the efficiency of the ventilation, is to sink a small pit in the solid floor immediately opposite the hole in the wall, and, instead of employing the row of drain-pipes, to let an air-brick in at the top of the pit so that it is flush with the floor, as illustrated in Fig. 12. A current of air will then be enabled to pass, but it is apt to cause cold draughts across the floor of the kitchen, which may give rise to a good deal of discomfort to the occupants of the room. This usually results in the air-brick being covered up, and it is therefore entirely prevented from fulfilling its own particular function. A remedy that could be adopted for this would be to fix a Tobin's tube on the wall instead of the air-brick, so that the current would pass in an upward direction and, being discharged into the room some distance above the floor, no uncomfortable draught would be experienced.

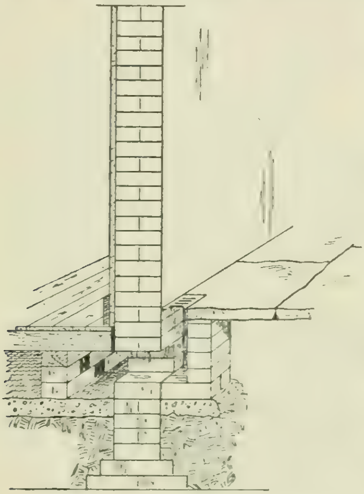

FIG. 12.—Method of Ventilation with Air Pit.

When the floors are damp in spite of the fact that the site has already been concreted, the trouble will in all probability be due to a weak, and therefore porous, concrete. This is almost certain to occur when the concrete is of poor quality, and not of sufficient density, as it will permit moisture to soak up from the ground by capillary attraction, and will be of very little use as a protection against rising dampness. The porosity of the concrete can easily be remedied by rendering the surface with 1 in. of waterproofed cement mortar, all dust and rubbish being first swept up and removed. It will be necessary to take the sleeper walls down in very bad cases, so that the rendering can be carried over the whole of the site. If this is carried out properly, no dampness can possibly rise. Dampness in the walls, due to a defective damp-proof course, must be remedied by rendering the walls inside with waterproofed cement mortar.

Asphalte also makes a good covering, and is quite impervious, but the site concrete must be dry before the asphalte is laid, or it will not adhere. This places asphalte out of court as a remedy against existing dampness, for the concrete will usually be so wet that it is quite useless to attempt to dry it out, and the only alternative is to wait until the moisture evaporates of its own accord ; this will take quite a long time, especially in the winter months. Cement rendering does not suffer under this disability, as a moist surface is necessary for its successful adhesion.

A thick coat of a mixture of coal tar and pitch, brushed on while hot, is an inexpensive, although not a very permanent, remedy, but the same objection holds good as with asphalte, and the necessity for drying the concrete applies equally as much. Whichever method is adopted, it must be carried out with the strictest attention to detail if it is to be of any use against the progressive effects of capillary attraction.

While the internal treatment of the floors should receive very careful attention, every effort should be made to keep the outside of the building perfectly dry. Broken and leaking eaves gutters are often responsible for much of the dampness that exists in cellars and underground apartments, as the water, instead of being conducted directly to the drain when it runs off the roof, is allowed to pour down on to the ground close to the wall. As a result of this neglect the foundations of the house become saturated, and the water percolates through the brickwork and trickles down on to the cellar floor. A similar result arises when the ground slopes down towards the house instead of in the opposite direction, as surface water drains towards the wall and gradually soaks in.

In a house in the north of England the cellar was invariably flooded to a depth of several inches during heavy rains, owing solely to the fact that rainwater was allowed to soak into the ground outside, and as water will always find its way towards a vacant space, a great deal of it was enabled to enter the cellar by passing through the brickwork. Under the circumstances, it was hardly surprising that dry rot broke out, and that the timbers soon fell a prey to the mistaken methods that were in force.

If the ground is naturally water-logged, or even if it is frequently saturated, a vertical damp-proof course of waterproofed cement mortar should be applied to the exterior of the wall, reaching from the foundation to a point 18 ins. above the ground. Another remedy is to construct an air drain round the building, this being perhaps the more effective of the two. As, however, the methods of remedying damp walls, important as the subject is, have already been exhaustively dealt with in another volume, they need not be considered at length here.

The foregoing measures for preventing the development of dry rot, and for ensuring its destruction once the disease has become firmly established in a building, will, if carried out carefully and conscientiously, be quite successful in achieving the object which is so much to be desired. Nothing, however, must be left to chance, or loopholes may be overlooked by which the disease—perhaps dormant for the moment, but only too certainly present—will eventually obtain a fresh lease of life, and the whole trouble will commence again and will have to be dealt with a second time. It may, perhaps, be considered by those who are not familiar with the subject that the remedies that have been suggested are unnecessarily drastic when it is considered that their only purpose is the exclusion, or at the most the extinction, of a rather primitive form of plant life, as the members of the vegetable kingdom are not usually so tenacious of life as to require such serious steps for their destruction. This, however, is not correct, as, far from being too drastic, the measures outlined in the previous pages are quite essential if adequate protection against further infection is to be ensured, and in many cases more serious steps still may be required.

If a room or a building is so permeated with the hyphæ of dry rot that they can be found in all the corners and dark places, the whole of the timber must be condemned without hesitation, and must be taken out and destroyed. When the case is extreme, and the whole house has been invaded by the disease, then all the timber in the building must be destroyed, and every inch of the wall disinfected ; here, however, the question will arise as to whether it is worth while going to the expense of reinstating the whole of the woodwork, having regard to the structural condition of the building and the probable time that it can be expected to endure. This, of course, can only be decided on the spot, and needs the attention of some one who is conversant, not only with the value of the property, but also with the probable cost that will be entailed in carrying out the repairs.

PART II

THE DEATH-WATCH BEETLE

CHAPTER V

THE COMMON FURNITURE BEETLE

THE second part of this volume will deal with quite another aspect of the destruction of timber, which originates in the activities of a very small, but extremely mischievous, insect known as the death-watch beetle. The damage that is wrought by this insect, while differing in many respects from the cause and effect of dry rot as described in the previous chapters may, if it is allowed to continue, ultimately become just as serious and endanger the structure to an even greater extent. While the decomposition of the timber that is caused by the uninterrupted attack of dry rot, results in the reduction of the fibres to a soft and friable condition without making any very great alteration in its external appearance until the last stages of the disease are reached, the injury that is generally wrongfully ascribed to the beetle itself is of a purely mechanical nature, which alters the whole physical structure of the timber, and reduces its strength to a degree corresponding with the limits which the destruction has reached.

Centuries ago, when the art of substitution had not been brought to its present state of perfection, the timbers that were employed in the construction of the roofs and floors of those buildings which possessed any pretensions to importance were of the very best English oak, and in nearly all cases the sectional dimensions of the various beams erred greatly on the side of safety, when compared with beams that are employed in similar positions to-day. This, no doubt, was partly due to the fact that the very accurate formulæ and calculations that are brought into use in designing modern structures were not known at that time, and rule-of-thumb methods had to be employed, so that really a great waste of timber was incurred in the construction of the buildings from the present-day view-point. This, however, was of little moment in those early and simple days, as timber and time were plentiful, and labour was cheap, and it is owing to these factors that our own generation is enabled to congratulate itself on the possession of so many magnificent examples of the old-time craftsman's skill.

The timber work in these old buildings was also more elaborately constructed and decorated with carvings, and there was not so much of the rush and hurry that is common to-day to cause any of the fundamental points in the design to be neglected. At the present time—which is commonly designated as the " steel and concrete age "—the many opportunities that were presented to the mediæval craftsman for the creation of a beautiful and symmetrical structure are often lacking, as neither steel nor concrete is capable of being wrought into such artistic forms as timber, and they cannot bear comparison with the latter material from this point of view.

While timber, being an organic substance, is peculiarly liable to destruction from many and varied causes, at the same time, when it is employed with discretion and under reasonable conditions, its durability is rather surprising. Instances of this were given in Chapter I., and when the rapid decomposition of practically any variety of timber that is subjected to the alternations of wet and dry weather is taken into consideration as well, together with the speed with which it may be destroyed by the various parasites to which it may fall a victim, it serves to emphasise the absolute necessity of using timber only in accordance with the requirements of its natural properties if a long life is to be ensured.

Timber, from its composition and structure, is particularly liable to the ravages of wood-boring insects, as it is more or less soft and contains certain digestible matter of which they are in need. The insects find little difficulty in penetrating to the interior of the wood, and bore their way along in all directions, where they obtain an ample food supply, by which they are enabled to carry on their destructive work ; and so the vicious circle is complete.

It is not only the softer coniferous varieties which suffer in this respect, as many of the harder species are equally liable to attack and are quickly demolished by the persevering insects. The damage that is caused at times is specially noticeable in the depredations of the white ant, which is such a scourge in tropical countries, making its persistent attacks on wood of all kinds until it is utterly destroyed. The white ant is fortunately not an inhabitant of this part of the world, for which we have much to be thankful, but in India it constitutes perhaps the most serious problem which consumers of timber have to face, and it also does a great deal of damage in Africa. The average life of railway sleepers in some white ant-infested parts of India is estimated to be about two years, and this waste of material is inevitable unless some protective treatment is applied before the sleepers are laid.

One of the peculiarities of the attack of wood-boring insects is that when they first commence operations, and for some time afterwards, very little evidence of anything wrong can be seen, so that a good deal of injury can often be done to the timber before their presence is discovered. Under these circumstances the danger is in many cases unsuspected until it is too late for any effective preventive measures to be taken. As a general rule, the insect bores its way along parallel with the length of the beam rather than across the grain ; hence there is less severance of the fibres, and the strength of the timber is not reduced so much as it would be if the burrows passed in the opposite direction. This, however, is not a very great consideration, as it is usually only a matter of time before the timber is perforated in such a way as to need complete renewal in order to prevent actual collapse. The process is necessarily slow, as the insects are usually of comparatively small proportions, but they are very persistent, and continue their depredations as long as any timber is left which they can consume.

There are quite a large number of insects which attack wood in this part of the world, most of which confine their operations to the living tree and whose activities result more in the ruination of the tree for timber purposes than in its complete destruction. Structural timber is immune from attack by these species of insect, and no description of their method of working is required in this volume.

Of the various risks to which timber is exposed after it has been employed in the erection of a building there is none more misleading, or more likely to end in its complete disintegration, than the successful attack of the death-watch beetle. This insect often goes by the name of the wood worm, although actually it has not the slightest resemblance to a worm either in its shape or its natural characteristics. It is, however, extremely persevering, and once it has obtained an entrance to the timber, it is only a matter of time before disaster occurs unless immediate and effective steps are taken to terminate its energetic career.

There are several species of beetle which are found in this country whose attentions are confined to timber and timber work. Of these there are two varieties which commonly go under the name of the death-watch beetle, but, although they belong to the same family, they are quite distinct both in their size and shape and in the class of timber which they select for attack. These two varieties are the common furniture beetle and the true death-watch beetle, and they are apt to be confused together owing to the similarity of their methods of working and to the fact that, at a casual glance, they are somewhat alike in appearance. The life histories of both of these insects are very much the same, each one passing from the egg to the larval stage, and then on to the pupa, which ultimately changes into the complete beetle. There is, however, a distinct difference in their size, and their general appearance is not really the same when they are closely examined, as the latter is nearly twice as large as the former and is quite different in the markings on its body. Both species operate in the same way, but the common furniture beetle is only found, as its name implies, in household furniture and fittings, while the death-watch beetle confines itself exclusively to the timbers that are used in the construction of buildings generally. The similarity in the results of their activities is very marked, as the timber is riddled through and through with the burrows of the insect until, in the later stages of the attack, it becomes nothing more than a mere spongy shell, containing large quantities of fine dust in its interstices, and if the timber is hammered or shaken violently, the dust is discharged in clouds from the holes with which the surface is perforated in all directions.

In the early stages of the attack little or no definite evidence can be found of the presence of the insect, as it works silently and completely out of sight, and it is only after a considerable time has elapsed that, its mission being performed, the beetle emerges into the light of day. This constitutes one of the most serious aspects of the problem of the destruction of timber beams by the death-watch beetle, for, in common with dry rot, the destruction may proceed apace, and the danger of the beams giving way may be imminent some time before the urgent necessity for giving them serious attention can be discovered.

Thus man and his works have been entirely at the mercy of one of the smaller members of the insect world for many years, and, up to the present time, it must be admitted that the honours in the fight for supremacy between the two have remained decidedly with the latter, and the beetle has won. A different tale can be told since the passage of the last twelve months, however, and the balance of power is now more evenly adjusted.

Most people are familiar at least with the appearance of so-called worm-eaten furniture, and it is questionable whether any dwelling-house is entirely without one or more examples of this form of deterioration, in the shape of tiny round holes in the wooden frames of chairs, tables, or other objects of general use. When furniture suffers in this way the work of destruction may continue until the object is rendered entirely useless, and the trouble may also spread to furniture in other portions of the building ; on the other hand, it may not increase beyond a few isolated holes in some particular article, as circumstances may arise by which the insect is exterminated before it has had the opportunity to multiply its species, or it may prefer to seek some more favourable situation in which its progeny can be sure of a wider field for their misguided energies. A piece of walnut furniture that is now in the possession of the writer, and which was made in a provincial shop more than forty years ago, remained quite sound for at least twenty years after it was first put together. Later on, however, unmistakable evidence of the attack of the furniture beetle was detected, in the shape of a number of exit holes, which gradually increased in number, and in the superficial area over which they were distributed, until the portion was reduced to a mere honeycomb and crumbled at the slightest touch. The attack was confined to the sappy portion of the wood, which extended along one side of the article, and it was maintained until all the sapwood had been riddled ; it then suddenly stopped, and no indication of further working has been discovered for the last ten years. The heartwood was apparently not touched, as there is not a single hole to be seen beyond the dividing line between this and the sapwood.

Many remedies have been advocated and practised for solving this troublesome problem, some of which will be described at length later on. It is, however, generally recognised that the complete extermination of the beetle, once it has obtained a secure footing in the timber, is a problem of some magnitude, and that the most thorough and painstaking measures are needed if any hope of success is to be assured.

The late Mr. William Stevenson, of Mansfield—one of the foremost authorities on timber and timber trees of his time—considered that there is no reliable remedy except the complete removal of the affected part and its replacement with new material ; in the light of the knowledge that was then available, this contention was no doubt correct, as, even if the insect could be completely destroyed, the damage would still remain and must needs be made good. Mr. Stevenson also remarked once on the comparatively few people who have ever seen the beetle, and

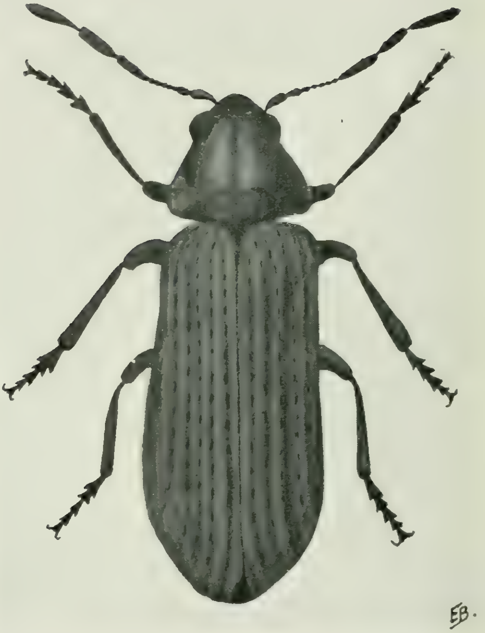

FIG. 13.—The Common Furniture Beetle.
(*Anobium punctatum.*) *Magnified fourteen times.*

this again is quite in accordance with the habits of the insect, as it soon disappears once it has left its original home, and if, in a few cases, it happens to be observed in some other place, its identity is probably not often recognised. A most interesting exhibit in this connection was recently shown to the writer by Professor Maxwell-Lefroy at the Royal College of Science. This consisted of at least fifty living specimens of the death-watch beetle that were being used for experimental and observation purposes, and it is probably the greatest number that have so far been seen together at one time. Some of these are illustrated in Fig. 20, in the chapter on the death-watch beetle.

An illustration of the common furniture beetle (*Anobium punctatum*) is given in Fig. 13. It is hatched from oval-shaped eggs, which are white in colour, and of such small dimensions as to be hardly noticeable to the naked eye without a good deal of searching. The full-grown perfect beetle is rather less than $\frac{1}{4}$-in. long, and is provided with the usual pair of hard wing cases, which protect the body and the true wings against injury. It is about $\frac{1}{20}$-inch in diameter, perhaps a little more, but the dimensions naturally vary somewhat according to circumstances. The actual size of any particular beetle can be estimated by the diameter of the hole through which it emerged from the timber. The exterior of the wing cases is of a dark-brown colour, and they have the appearance of being decorated with rows of very small spots, which run in parallel lines from the front to the back. The spots, however, when closely examined, are found to be due to the presence of a series of shallow grooves, these being broken up by a number of tiny indentations or depressions, which are set side by side along the grooves. The beetle possesses six legs, as shown in the illustration, and a pair of very delicate antennæ, each of which has eleven Joints.

The eggs are laid by the female beetle about the month of June, soon after it has emerged from the wood. After pairing with the male insect, the female commences an investigation of the likely places in the vicinity in which they can be deposited and where they will be out of the reach of danger. The eggs are usually laid in cracks or crevices in the wood, or in open joints where the timber may have shrunk and the furniture come slightly apart. To facilitate their projection below the surface the female is provided with a long flexible ovipositor, which is capable of being extended, so that the eggs may be lodged in a place of safety. As a rule, two or three eggs are laid in each crevice, this being repeated in several different places, and perhaps in different numbers, until somewhere about twenty have been safely deposited. The eggs are not often laid on exposed surfaces, on account of the danger that would exist of their destruction.

The second stage in the life-cycle of the beetle is the appearance of the larva or grub, which is hatched out of the egg from two to four weeks after it has been laid. The newly hatched larva of the common furniture beetle is very small, but when full-grown it reaches to about $\frac{1}{5}$-inch in length. Although the grub is quite soft, its jaws are immensely strong to enable it to bore its way through the hardest timber, a really marvellous performance from all points of view. As it makes its way along, the larva obtains a plentiful supply of food from the albumen in the wood, which is extracted from the dust or borings as they pass through its digestive organs ; thus the damage that is caused to the furniture is perpetrated to satisfy the natural appetite of the insect, which obtains its food supply from the timber, while the latter also provides it with a suitable habitation and only too secure a protection against external enemies. The burrows are naturally very small at first, but as the larva increases in size the diameter of the boring expands to about $\frac{1}{12}$-inch. This, of course, is very small, and if only one burrow was present no great harm would be done, but when the numbers are increased indefinitely, each one passing within the smallest fraction of an inch of the others, very different conditions are produced.

The colour of the grub is mostly white, being rather darker at the front, while the jaws are nearly black. An illustration of the full-grown larva of the death-watch beetle is given on page 140, showing its general shape and the provision that Nature has made to enable it to bore its way in any direction through the timber. The latter is most interesting as a mechanical contrivance ; it is shown to a larger scale in Fig. 16. There is very little difference in the larva of the two beetles, except for a slight variation in the size.

The larva has three pairs of legs, which are situated at the under side of the first three segments of the body, each leg being very short and having five joints. The remaining segments are provided on the back with a double row of small spines or needle points, projecting outwards, to enable the larva to force its way along the boring ; this it does by pressing the spines tightly against the wood at the top and sides of the burrow, and so obtaining a hold, which it uses to push itself a little further forward, biting at the wood at the same time. The small black spots along the under side of each section in the illustration are the spiracles, or breathing holes, which permit the passage of air to the interior of the body. There are nine of these apertures on each side of the larva. As the boring continues some of the particles of wood are rejected as they are bitten off and some are swallowed, and after the albumen has been extracted by the digestive organs the residue is passed out again into the burrow behind the larva, so that the opening is completely filled up ; and so the larva exists and works in practically nothing more than a hole in the centre of the wood, and very little air can obtain access for it to breathe. The burrows do not necessarily proceed in a direct line with the grain of the wood, as they may deviate at times and turn off in another direction ; this always occurs as the grub nears the end of its existence, but as a rule the burrows are fairly straight and parallel with each other.

The growth and development of the larva continues as time goes on, and the skin is shed at certain intervals until the larval stage is passed and it makes

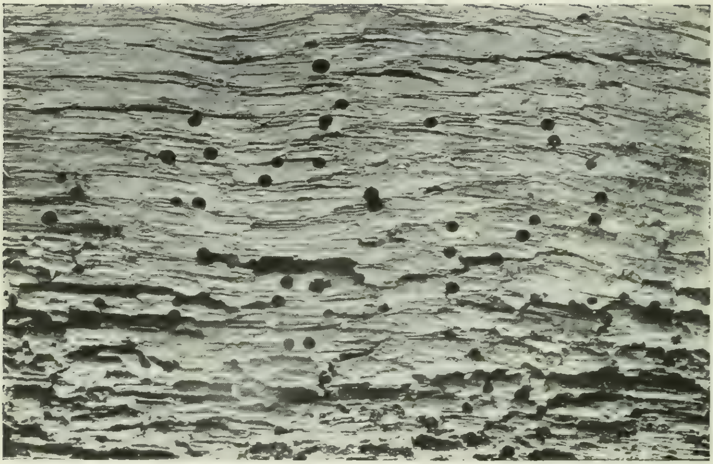

FIG. 14.—Exit Holes made by the Common Furniture Beetle (natural size).

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preparations for undergoing the second change of its existence into the pupal stage.

When the pupation period approaches the larva alters its course and burrows outwards until it comes quite near to the surface of the wood, where it stops short without actually boring right through to the outside. Here the larva enlarges the end of the burrow into a small chamber, blocking up the way by which it has come with a thin saucer-shaped pellet of wood dust, cemented together with a resin-like substance, which ultimately sets as hard as the wood itself. In this chamber it is secure against danger, and it passes from the larval stage into a pupa or chrysalis, this being the third stage in the life-cycle of the insect. The pupa is of a rather soft nature, its colour being white, and it remains within its self-made prison cell until, after about two or three weeks, its metamorphosis is complete and the perfect beetle is formed.

The beetle stays in the cell until its body becomes firm and solid, when, its jaws having developed into a hard and serviceable weapon, it bores its way through the remaining thin skin of the wood and emerges into the open for the first time in its existence. An illustration of a piece of timber showing the exit holes of the furniture beetle is given in Fig. 14.

The actual time that is occupied in the complete life-cycle of the insect from the egg stage to the perfect beetle appears to be in some doubt, as each stage is passed, and the several transformations occur, in the interior of the wood, so that it is impossible, in an ordinary case, to actually see what is going on, and conclusions only can be drawn from the various data that are available. This, of course, makes it difficult to deal effectively with the pest, but if only its presence could be detected in its initial stages much, in fact most, of the damage that is wrought by the grub could be prevented, and steps could be taken for its destruction before it had time to change its habitation and infest other material. Dr. Gahan, the Keeper of the Department of Entomology at the Natural History Museum at South Kensington, who has made a very close and prolonged study of the subject, estimates that " the whole life-cycle, from the laying of the eggs until the beetles appear, must take at least a year or almost a year for its completion," but he also states that " we have reason, however, to believe that when living in dry, old furniture it generally takes two years, if not more, to complete its whole development from the egg onwards to the perfect insect." Other authorities concur in the opinion that " it is one year, as a rule, in the case of this species when living out of doors in the dead branch of a shrub or tree." Dr. Gahan, when investigating the matter, found that early in March larvæ in two or three different stages of development were present at the same time in the same piece of timber, and as these could not all have come from eggs that were laid in the preceding year they must have belonged to at least two generations, and probably were of three different generations. In some of the species of furniture beetle three years, or even longer, may be occupied before the metamorphosis is complete.

It is not often that the beetle itself can be observed on emerging from the wood, as it flies away to continue its work of destruction in other directions immediately it has bored a passage from the chamber where pupation has taken place. Many people have heard the tapping noise which is made by the beetle without having had the doubtful satisfaction of seeing the actual insect itself. An explanation of the noise, its meaning, and how it is caused, is given in the next chapter.

It is quite a common belief that the " worm holes " in furniture are made by the beetle as it bores its way into the wood, and that from the point of entrance it tunnels through the timber, causing the destruction that is only too familiar to most people. This, however, as will already have been gathered, is not only incorrect, but is just the reverse of actual fact, as by the time the holes are discovered the work of destruction has been completed, so far as the particular insect which made them is concerned, and the beetle has disappeared in search of other promising situations where it can lay its eggs.

There are quite a number of remedies that can be adopted, with varying degrees of success, for the extermination of the furniture beetle, but while each method may be quite effective under certain conditions, it should be recognised that it is practically useless dealing with the exit holes that may be found in the surface of the wood in the hope of destroying the beetle within, as it would be merely a case of locking the stable door after the horse had gone. This is only a broad statement, however, that must be qualified to some extent, as it is quite within reason that the female beetle, after pairing, may have deposited her eggs within the entrance of some of the holes, and with a suitable treatment they could easily be reached and destroyed ; thus further trouble might be averted, or at least reduced. In addition to this, if a liquid were to be injected into the holes, although it could not come into immediate contact with either grubs or beetles, it would be enabled to soak through the walls of the burrows and so to reach any other larvæ that might still be working their way out.

A very simple method that is frequently adopted for dealing with worm-eaten furniture, when the article is not too cumbrous, or of such a delicate nature as to be injured in the process, is to completely immerse it in a bath of paraffin and to leave it there for some little time. Paraffin is deadly to the insects, and as it is enabled to penetrate into the interior of the timber by way of the exit holes, and to soak through the fibres until it reaches any pupæ or grubs that may still be actively engaged in other portions of the wood, it quickly solves the problem of their extinction.

It should be noted, however, that before the paraffin can enter the burrows the air that is within must be expelled, and that it can only escape when the exit hole faces upwards. Hence the article must be turned over occasionally to allow the air to rise to the surface, its escape being facilitated by pushing the end of a thin wire into the opening when the air refuses to move. Large articles of furniture, and those which are upholstered with leather or other soft material, obviously cannot be treated by this method, as in the one case a tank of such large dimensions would be required, and in the other the upholstering materials would be irretrievably damaged. With this class of furniture the liquid should be applied with a brush, being spread liberally over the surface, so that it can be absorbed, and thus make contact with any pupæ that may be in the process of transformation just below the surface of the wood. It is useless to apply the liquid to any part of the furniture that has been painted, varnished, or polished, as it would be unable to soak in ; thus only those portions of wood at the back and underneath which are quite bare should be dealt with. In serious attacks the treatment should be repeated annually about the months of May or June, that being the time when the beetles emerge and the eggs are laid, and when they are most vulnerable to attack. By giving a yearly application of the paraffin, any pupa that may have come to the surface too late to feel the effects of the previous year's treatment will be destroyed before it has the opportunity to emerge as a beetle, and to perpetuate its species by laying eggs in other portions of the furniture. It is also a good plan to brush the joints and crevices of the furniture over frequently with paraffin, as this would have the effect of destroying any insects with which it came into contact, while the deposition of fresh eggs by the female beetle at a later date would be discouraged, as the odour of the paraffin is distasteful to most forms of insect life.

Other liquids that have been recommended for saturating the timber, both as a cure and a preventive, are vinegar, benzene, petrol, turpentine, and naphthalene dissolved in carbon tetrachloride, all of which exert a destructive influence on the insects. Bichloride of mercury, dissolved in methyl alcohol, produces a particularly strong and poisonous mixture. This solution should be made up in the proportion of one part of corrosive sublimate to twenty parts of alcohol, and it must be brushed on to the wood with the greatest care. The methyl alcohol penetrates readily into the timber and acts as a vehicle, carrying the corrosive sublimate with it ; it then evaporates, leaving the more solid portion of the solution to carry out the object for which it is intended. As observed in Chapter IV., corrosive sublimate must be handled with extreme care, as it is of a highly poisonous and corrosive nature ; it should always be kept securely under lock and key when not in actual use.

Another method that has been suggested as a means of destroying the furniture beetle is to smear the woodwork all over with mercurial paste, which is fatal to the insect in a very short time. As, however, there would be little likelihood of the paste penetrating deeply enough to reach the grubs, or even the pupæ in some cases, it is doubtful whether, considering the risk and trouble that is incurred when employing this method, the efforts and inconvenience that are involved would be adequately repaid.

Some time ago the *Deutsche Tischler-Zeitung*, in a discussion on the subject, suggested that either turpentine, benzene, petroleum, or alcohol should be poured into the boreholes—or, alternatively, it might be injected with a syringe—the holes afterwards being stopped with putty. The article also went on to say :—

> " Tests have been made successfully by sprinkling the wood with boiling hot soap lye, mixed with salt water. If this is followed by closing the holes with a mixture of glue and putty, the worms will be effectively killed, as their air supply is cut off, even if they should have escaped the soap lye. In place of the lye, carbolineum can be used, provided that there is no objection to the odour.
>
> " Better, and just as cheap, is the method which coats the wood with a calcium or lime sulphate solution or with sulphuric acid, repeating this process several times. These liquids penetrate deeply into the wood, kill all organisms, and are easily applied. The only drawback, that of fuming during application, can be guarded against without much difficulty. The liquids evaporate rapidly, so that there is no danger for any length of time."

The former method, while doubtless being quite effective so far as the destruction of the larvæ or pupæ is concerned, appears to overlook the fact that, by the time the holes are visible the burrows have been vacated by their former tenants, and the only method by which the insects could be destroyed is by the penetration of the liquid through the fibres of the timber. This might possibly occur provided that the application of the liquid was plentiful enough for the wood to become well saturated, but it would appear that the trouble of stopping the holes would be unnecessary so far as the immediate object of destruction was concerned. In any case the grubs must require but a very limited supply of air for their existence, as the burrow is completely closed by the wood dust which is ejected by the insect as it works its way slowly along ; possibly the air supply is obtained through the pores in the timber.

"Evans' Patent Wood-worm Killer" is a ready-made liquid preparation that can be obtained for treating furniture in all stages of decay. The solution is brushed on to the affected part of the wood, using a stiff brush and rubbing it well into the exit holes. The article must be allowed to stand in a dry place for a few hours after the application, so that the liquid can soak into the deepest crevices in the wood. It is claimed that this treatment destroys the beetle and grub, and renders the furniture immune from future attack. A special preparation is supplied for filling in the exit holes after the treatment has been completed. The cost of the solution varies from 2*s*. 6*d*. for a half-pint tin down to 21*s*. per gallon, and the stopping from 1*s*. to 4*s*. per tin.

Little protection can be obtained by the use of an alternative kind of timber that is not likely to be attacked, as most varieties suffer in this respect, and once the eggs have been hatched out, and the larvæ have started on their life's journey, a difficult problem has been created that needs a great deal of care and circumspection for its successful and complete solution.

There are two additional methods of dealing with the trouble when circumstances permit of their adoption, *i.e.* (1) treatment by heat and (2) fumigation with a gas or vapour. Both of these methods are recommended by Dr. Gahan for use under suitable conditions, and he states that the heat treatment is undoubtedly one of the quickest and most effective methods of destroying the grubs in worm-eaten furniture and wood, a statement that will readily be agreed with. Dry heat is the best form of application, but it must be used with discretion. The heat must reach to the centre of the wood, where the temperature should be raised to about 130° Fahr. or a little more, and if the timber is not more than an inch or two in thickness this can be effected by subjecting it to about 212° Fahr. for an hour or so. Small articles of furniture can be baked in a gas oven that is regulated to the required temperature, while small flat articles can be treated by placing them on top of a hot-water cistern when the circulation is active; for larger movable objects a special hot-air chamber of suitable dimensions would need to be constructed, if such were not already available. Most of the more up-to-date municipalities and many of the institutions, in towns of any importance, possess a heat disinfecting apparatus that could be utilised for the purpose at a very small charge. It is evident, however, that highly polished articles, or delicately carved wood furniture, could not safely be subjected to a temperature as high as this, as it would inevitably suffer considerable damage, either by the splitting of the timber or by the destruction of the film of polish. This shows that the heat treatment cannot be safely employed in cases of this description, and other means must be adopted that are less likely to cause more injury than the disease which it is intended to counteract.

The second method which is suggested by Dr. Gahan, that of fumigation with a gas or vapour, is not so liable to injure either the woodwork or the upholstery of the article, and it also has the advantage that it can be carried out without a great deal of expense or tedious preparation. The principal part of the apparatus that is required for the treatment consists of an airtight box or similar receptacle, of sufficient size to contain the article that has to be dealt with. A large wooden box, in which any open joints or crevices have been pasted over with paper, can be utilised for fumigating any object that can be accommodated inside ; an iron tank with a tightly fitting cover is also suitable, or even the humble dustbin, so long as it is clean, and the top is hermetically sealed, either by bedding the cover on with putty or by closing the opening with a special wooden lid. Larger articles of furniture can be treated by standing them in an ordinary room in such a manner that the air can circulate freely all round each piece, the crevices round the doors and windows and the mouth of the chimney being covered with paper pasted over the openings, so that the fumes cannot escape during the process.

Gas or vapour will penetrate into the system of burrows more readily than a liquid, and will thus have a more far-reaching effect, but the operation must be carried out intelligently or more harm than good may be done by the treatment.

Hydrocyanic acid gas is the most potent for destroying the insects by fumigation, but, being a most deadly poison, it needs to be handled with the utmost care, and it should not be employed by any but those who are expert in its use, as certain precautions are necessary to prevent accidents occurring to those who may be in the vicinity. *Carbon disulphide* gives off a heavy vapour, which is also very effective, and is not quite so dangerous as *hydrocyanic acid* gas, but this has the disadvantage of a low ignition temperature, and it is also liable to explode when mixed with air. Taken on the whole, it is advisable that both of these materials should be avoided by those who are not skilled in such matters, and that some less dangerous method of fumigation should be employed.

Sulphur dioxide gas can be used with advantage for fumigating purposes, provided that the article to be treated is not of such a nature as to be spoilt by bleaching, and that there are no metallic parts to tarnish. The gas can be generated by burning a sulphur candle in the receptacle ; this can usually be procured at the local chemist's or oil-shop. It can also be obtained in liquid form in steel cylinders, and can be forced into the pores of the wood under its own pressure by the aid of suitable appliances. Another method of using *sulphur dioxide* gas is by dissolving camphor in the liquid and afterwards spreading it over the wood with a brush. The result of this treatment is that the liquid sinks into the wood, while the camphor crystallises on the surface into a solid crust, which prevents the evaporation of the liquid in the form of gas.

The old-fashioned method of fumigating with brimstone is probably more familiar to most people than that in which the liquid form is used ; the materials are also more easily procured, and they are quite simple to handle. It is, however, essential in this, as in the other cases where gas is employed, that the receptacle or chamber in which the fumigation is carried out should be perfectly airtight, or the fumes will escape before they have done their work. When the larvæ are present in movable objects of furniture, or in the wood fittings in a room that can easily be made airtight by pasting strips of paper round the doors and windows, little difficulty should be experienced in putting the process into operation.

The method by which the gas is generated is to stand a pail full of burning coke on a flat stone or a sheet of iron in the centre of the floor and to burn a few handsful of brimstone in an iron pot or saucepan over the fire. This will speedily give off large volumes of dense, suffocating fumes, and should be left until the room is completely filled, the door being locked and the crevices round the edges pasted over from the outside as described. A word of caution is necessary in this connection, however. Before leaving the room it is most important to make perfectly sure that the fire is quite safe, and that there is no possible chance of burning coals falling out of the pail on to the wood floor, or the remedy may be considerably more expensive than the disease. A sheet of iron or stone at least 3 ft. square should be used on which to stand the pail, and a border of bricks on edge, in the shape of a fender all round the sides, will go far to prevent any danger of a conflagration should anything untoward happen in this respect. Whenever it is possible, an occasional watch should be kept on the fire through one of the windows of the room.

Another method by which the risk of fire can be considerably reduced is to dispense with the coke fire and to burn the brimstone in the pot by pouring methylated spirits over it and then applying a light; the pot should be stood in a dish of water beforehand to reduce the risk still further.

Benzene gives off a vapour which is very effective, but as it is highly inflammable, special precautions must be taken to prevent the admission of a flame to the vapour, or a danger of fire will arise. The benzene should be placed in saucers or shallow dishes in the bottom of the fumigating chamber, and as the fumes rise they will completely envelop the article that is in process of treatment, penetrating into all the holes and crevices and totally destroying all forms of life. *Carbon tetrachloride* is another very volatile liquid, which is safer on the score of fire risk than benzene, as it is less inflammable. As this liquid gives off a heavy vapour, it should be placed in open vessels in the *top* of the fumigating chamber; the vapour will then fall to the bottom, until the interior of the chamber is completely filled with the fumes.

Liquid ammonia also gives off a vapour which is lighter than air, and will therefore rise to the top; it is quite easily procurable.

A Commission that was appointed by the Science and Art Department in 1864 to inquire into the best method of destroying the larvæ in the wood carvings at the South Kensington Museum, recommended that fumigation with benzene vapour should be adopted for the purpose, and as a preventive measure against future attack, the Commission advised that the wood should be painted over with a solution of mercuric chloride in methylated spirits, or in parchment size, the proportions in either case to be sixty grains of chloride to one pint of the liquid ; this is something less than a 1 per cent. solution.

The timber that is used for structural purposes in barns and outbuildings of all kinds is now very frequently creosoted under pressure, a treatment that is so thorough that the preservative medium penetrates to the core ; this is very effective both as a preventive remedy against the attack of wood-worms, and also as a means of destroying any eggs or larvæ that may have been deposited or hatched in the cracks of the timber, the destructive effects of the creosote being due to the phenol or carbolic acid which it contains.

The use of creosote for impregnating timber that is used for the interior work in dwelling-houses is obviously out of the question, as the smell would be objectionable to the majority of occupants. It is even more unsuitable for the treatment of furniture, as, in addition to the odour, the colour of the creosote would operate against its usefulness as a preservative medium for fancy woods. The question of the relation of the beetle to structural timber and the most effective means of its destruction is discussed in the next chapter, which deals with the true death-watch beetle, a more frequent visitor to buildings generally than *Anobium punctatum*, but the same steps would be required in the case of an attack by the latter. Much waste of timber from wet or dry rot, and from the attacks of insect pests and vermin, could be effected if a more general use were made of this simple but excellent remedy ; fortunately the general public is beginning to realise the uselessness of the tremendous waste of timber that has been allowed to take place in the past from preventable causes alone, and the practice of creosoting is now becoming more popular.

It needs but a very superficial study of the life history and the habits of the furniture beetle to become convinced of the dangers that will arise from neglect when a house has become infested with the insect, and it will be realised at once that widespread damage may be caused if something is not done to relieve the situation without delay. It is certain that in an attack by the beetle—more so than it is with dry rot—the visible evidence of the havoc that is being wrought within does not appear until the damage has been done, that is, so far as the individual insect is concerned. But where one beetle is known to have existed by the appearance of the hole through which it emerged from the timber, it is quite probable that others are even then steadily engaged in their persevering efforts to render the wood as worthless as possible, and at the first signs of serious damage in this direction, some remedy or other should be put into operation with the object of bringing their efforts to an abrupt conclusion. It is only by drastic measures that this can be accomplished.

The actual damage that is caused to the particular piece of timber that is the subject of attack is not the only consideration, either, as if the matter is neglected or postponed, and the beetles are allowed to escape from their burrows, the chances are largely in favour of other articles of furniture in the vicinity becoming infested and ultimately destroyed in the same manner. Thus the process of destruction would continue to increase in magnitude as the insects multiplied in numbers, until even the whole building might be involved in ruin, and it is quite possible that exceedingly valuable specimens of craftsmanship, both from an artistic and a historical point of view, would be lost for ever. The futility of dealing with the matter in a half-hearted, haphazard sort of manner should be recognised by the least intelligent person, and if the problem is not given the attention it deserves, and is allowed to take its course without any attempt being made to prevent further damage, the blame for future developments would have to be laid on the shoulders of those who were too indolent to exert themselves, when the opportunity for effectively combating the growing danger was presented.

CHAPTER VI

THE DEATH-WATCH BEETLE

WHILE the damage that is wrought by the common furniture beetle may be, and often is, of the most serious nature, owing to the destruction of priceless furniture and works of art, these losses, unfortunate and regrettable though they may be, naturally do not involve any danger to life and limb, neither do the activities of the larvæ as a rule endanger the fabric of the building in which the furniture is housed. It is quite possible that in selected cases, the pecuniary losses that are caused by its burrowing propensities may considerably exceed those which are involved in the work of its near relative, the death-watch beetle, this being due to sentimental rather than economic reasons. In many instances, however, this misproportion may be entirely reversed, as witness the damage that was wrought by the death-watch beetle to the roof of Westminster Hall, where both the sentimental and the material values of the structure that was so nearly lost to the nation reached exceedingly high figures. A brief description of the very narrow margin by which this wonderful roof was saved for future generations and the methods that were adopted for exterminating the insignificant, but very active and destructive, author of the trouble, is given in succeeding chapters.

The death-watch beetle, *Xestobium rufovillosum*, or, as it is more generally known, *Xestobium tessellatum*, confines its activities exclusively to structural timbers, and is practically identical in its methods and habits with the common furniture beetle described in Chapter V. Both of these insects are members of the same family of Anobiidæ, and are very much alike in their general appearance, but the former attains to somewhat larger dimensions when full grown than the latter. It is estimated that *Xestobium tessellatum* passes through a complete life-cycle in approximately three years, during which time it progresses through the incubation, larval, and pupal stages, until in due course it makes its final change into the perfect beetle.

A great deal of superstition was attached to the visit of the death-watch beetle in the minds of credulous folk many years ago, and, indeed, there can be little doubt that a firm belief in its prophetic power is still deeply rooted in the minds of many of the less enlightened classes to-day. The superstition that was held consisted of the idea that a certain tapping noise that is made at intervals by the beetle was a forerunner of the approaching death of some member of the household in which it occurred ; this belief existed very generally for many years, and it was only displaced from its secure position amongst the pet theories and delusions of quite a large number of the public, when the results of a close observation of the habits of the insect proved the inaccuracy of the belief. That the noise is somewhat unusual will not be disputed, as it bears a good deal of resemblance to the intermittent ticking of an old-fashioned watch; hence the popular name that was given to the beetle, and which has clung to it for so long. Superstition, however, is notoriously very hard to kill, and it will probably be many years before the old belief is entirely superseded in the minds of those who still hold to it faithfully, by the more up-to-date and scientific explanation which has since been accepted by all reasonable people.

The tapping that has been the cause of so much consternation is made by the beetle with a clearly defined object in view. It is in reality nothing more than a sex call, and it constitutes the natural means of communication between the male and the female insects just prior to pairing.

The noise is produced by the beetle when calling to its prospective mate, by erecting itself firmly on its legs and jerking its body forward rapidly from eight to ten times, striking its head sharply against the surface on which it stands at the same time, each succession of taps being given out in the space of about one second of time. If another beetle is within hearing, and the call is accepted, it is immediately answered in a similar manner, and thus a convenient means of communication is established between the two. The tapping or ticking is generally heard in the late spring, when the beetles emerge from the wood and when their instincts warn them that pairing time is at hand. During the course of his investigations into the habits of the insect in 1917 Dr. Gahan confined a female beetle of this species in a small wooden box, and found that during the ten weeks in which she was under observation, the beetle could readily be induced to answer a call that was made by tapping a hard object in the vicinity with the point of a pencil, the imaginary call being responded to by the beetle striking her head against the sides of the box as explained. Dr. Gahan states, however, that he has never witnessed the tapping coming from the common furniture beetles, although he has many times kept them under close observation during the pairing season. The writer was informed quite recently by the clerk of works in charge of the restoration of St. George's Chapel at Windsor that the beetles, which were present in the timber work in large numbers, could often be persuaded to reply to signals that were given in this manner, and that the experiment was frequently tried by the workmen who were engaged in carrying out the operations.

When the larva has passed from its pupal stage into the complete beetle, and has bored its way out of the wood, it immediately takes flight, and, instinctively following the natural law of sexual attraction, it pairs with a suitable mate without loss of time for the purpose of reproducing its species. The female beetle may be impregnated in any convenient situation, not necessarily on the timber that will ultimately be the receptacle for her eggs, but, on the consummation of the union she at once commences a search for a suitable place in which the eggs can be laid. When this has been discovered, she deposits the eggs in any of the dark crevices and cracks in the timber, where they will be shielded from draughts and external interference, and having completed her mission, in the course of a few weeks she dies, leaving behind a fruitful legacy of potential trouble if the eggs are allowed to hatch. At this period the most favourable opportunity is presented for controlling the increase in the number of insects, and a constant war should be waged in all possible places where the eggs are likely to have been laid, so that they can be destroyed before any harm has been done. There is but a very little difference between the colour and shape of the eggs of the death-watch beetle and those of the furniture beetle described on p. 115; the former are, however, nearly twice as large as the latter.

A close resemblance also exists between the larvæ of the two species of insects. The chief point of difference lies in their respective dimensions, the larvæ of *Xestobium tessellatum* being proportionately larger than those of *Anobium punctatum*. The larva of the former species is provided with numbers of minute spines or horns, which project from the front portion of each segment of its body in a slightly backward direction in the same way as the furniture beetle. The spines are set in diagonal rows, and are very numerous; they assist the insect to drive its powerful jaws into the timber, and thus to bore its way along in such a remarkable manner. But for the presence of these spines the progress of the grub would be far less rapid, and much less damage would be done in a given time. The larva is illustrated in Fig. 15, the actual dimensions being shown by the smaller drawing.

Fig. 16 shows enlarged front and side views of the larva of *Xestobium tessellatum*, the head and the first three segments of the body only being given. The jaws are fashioned in rather a peculiar manner, the cutting edges being serrated to assist in the removal of the wood. When at work the jaws open sideways, as shown in the front view, and they are brought closely together with a sweeping, clasping motion, which gives the impression of great strength and a wide field of action. The colour of the jaws is a deep tortoiseshell brown, gradually darkening towards the cutting edge, where it is nearly black. It will be noticed that the head is almost round when viewed from the front and elliptic from the side. In colour the head is a transparent yellowish white, and is thinly covered with very fine golden hairs. The legs are quite small and very slender, the stomach is flat, and both are also furnished luxuriantly with hair. The illustrations were drawn from larvæ which have been under observation by the writer for some time past.

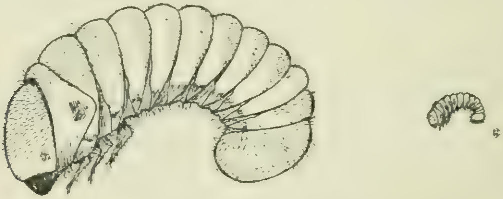
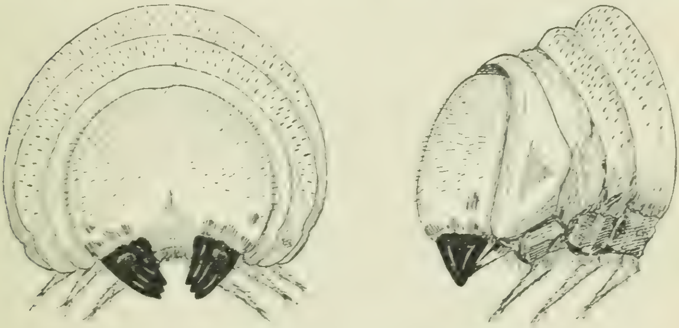


FIG. 15.—Larva of the Death-watch Beetle.

The larva is very small when it is first hatched, but it attains to a length of nearly ½ in. when it is full-grown. It is quite soft, and has the distinguishing characteristic of two small black spots or eyes on each side of the head, instead of the one that is possessed by the common furniture beetle ; in the mature grub the eyes are scarcely distinguishable from the surrounding portion of the head, as they are practically the same colour and but faintly marked. The body is white, and is curved as shown in Fig. 15 ; when removed from its burrow, the grub doubles itself up closely together. There are twelve segments to the body, the posterior segment being much wider than the others, the end being slightly flattened and covered with spines. In all other respects the larva of the death-watch beetle is very similar to that of *Anobium punctatum*, and it passes through the same stages in its natural development.



Front View. *Side View.*

FIG. 16.—Enlarged Head of Death-watch Beetle, magnified fourteen times.

An interesting illustration of the grub confined in its burrow is given in Fig. 17. This is taken from a photo, and indicates the method by which the spines are pressed into contact with the wood to obtain a purchase by which the larva is enabled to push itself along.

The subsequent history of the grub is one of ceaseless activity so far as is known. Immediately the incubation process is completed it commences to bore into the wood, and as the eggs have been deposited with a keen eye to future requirements, every facility is provided for giving the diminutive insect a good start. As a rule, the sapwood is most favoured by the grub, but the whole of the timber becomes riddled through and through in time, nothing being left but a mere skeleton of the original. Other timber that may be attached closely to the infested beam may also ultimately fall a victim to the general destruction, as the larva will bore straight through from one piece to the other at the point of contact, without regard to the relative directions of the grain. As a rule, the softer portion of the annual ring is attacked first, the burrows passing between two of the harder autumn-formed layers. In one beam that was taken from St. George's Chapel practically the whole of the softer portion had been consumed, the harder rings being merely perforated to permit the passage of the grubs to other parts of the beam ; thus the timber consisted in places of a number of concentric rings almost entirely separated from each other, every particle of the soft wood having been eaten away. Fig. 18 illustrates the extent to which this beam had been destroyed at the end, its sectional dimensions having originally been about 8 ins. by 4 ins. As a result of the practice of passing from one beam to another, the whole of the timbers in a roof or floor may be gradually reduced to powder, irrespective of their position or extent. Isolated pieces

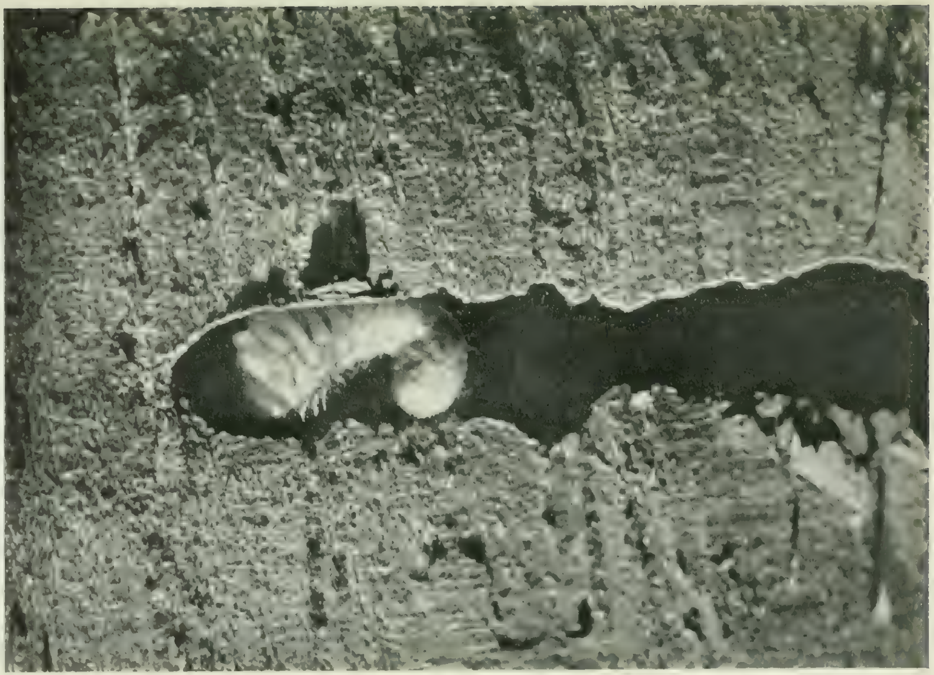


FIG. 17.—Larva of Death-watch Beetle in its Burrow.

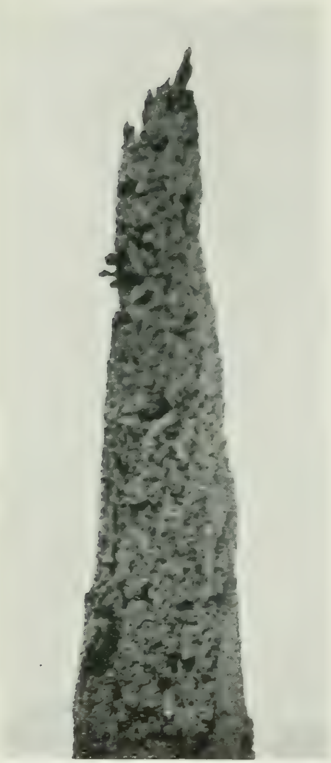


Fig. 18.—End of Badly Eaten Oak Beam.

of timber that are not in contact at any point with the larger beams may be preserved against attack for some time, but even these may be infested in other ways.

The larva itself suffers under one considerable handicap so far as its own individual locomotion is concerned, as it is difficult, if not altogether impossible, for it to move about on the surface of the timber, and thus to change the scene of its operations. This partial helplessness arises from the fact that the legs are small and not adapted for crawling on flat surfaces, while, being placed all together quite near to the head, and the body being curved, the grub has no means of balancing itself, in a position where it is unsupported at the sides ; the larva is thus unable to bring the spines into effective use to assist itself along, and can only wriggle about from side to side in its vain efforts to make some advance. Put the grub into the entrance of one of the burrows, however, and its progress is much more rapid and businesslike. Yet, in spite of the difficulty of locomotion, no timber in the vicinity can remain unaffected for any length of time without the assistance of some protective treatment, for when the female beetle emerges and has paired, she soon discovers that there is fresh scope for her attentions and promptly lays her eggs in its crevices ; it is then only a matter of waiting until the usual results occur.

The method by which the larva obtains its food supply by the consumption of such an unpromising material as wood is interesting as illustrating the remarkable provision that is made by Nature for the support and well-being of all her creatures. It is the albumen that is contained in the wood that supports life in the grub, and when the wood has been bitten off in very minute particles it passes into the interior of the grub, where a store of yeast is reserved. Some of this yeast is mixed with the wood dust, and this causes it to ferment, so that the food particles can be extracted and utilised for the purposes of nourishment. This has been noted by Professor Maxwell-Lefroy, who states that " the grub, which does the tunnelling, has within its stomach an organism of a microscopic kind similar to a yeast, which is apparently a necessary factor in the digestion of the wood : this organism exists also in the adults, is probably deposited on the egg when it is laid, so that the grub becomes infected with what is apparently a necessary adjunct to its digestion ; similar instances are known in related wood-boring grubs ; and the point may ultimately prove to be of more than academic interest, as one might well be able to sterilise the egg of its yeast without killing the egg, but still make life in the timber impossible for the grub."

The life-cycle of *Xestobium tessellatum* is probably a little longer than that of *Anobium punctatum*, about three years being occupied from start to finish. Some authorities have held that the development of the beetle from the egg in the former case is completed in one year, although no absolute proofs of this are in existence. As the various changes take place entirely inside the timber, considerable difficulty has been experienced in making accurate observations on this point, and the question still remains in some doubt.

As, however, it has been proved conclusively that the larvæ have existed for a period of nearly three years in several cases, the probability is that the longer term is correct.

A good deal of doubt also exists as to the actual movements of the grub during its existence, and the amount of damage that is caused by each separate insect. This cannot be estimated from an examination of the burrows, as they usually cross and recross each other so frequently that it is impossible to say which is the beginning and which is the end ; hence the length of any particular one cannot be ascertained. It is likely, however, that the operations of one single insect do not extend over a very large area, the collective amount of damage being due to the lengthy period over which many generations of larvæ have been at work. Experiments are now being made with the object of deciding both of these points, and in due course they will be settled beyond dispute.

There is yet something to learn also with regard to the time when pupation takes place, as the grubs have been found in different stages of development at one and the same time. It is considered that this, the third stage in the life of the insect, occurs during the late summer or early autumn, and that the beetles, instead of leaving the wood very shortly after they have passed the chrysalis stage as in the case of *Anobium punctatum*, remain in the pupation chamber through the winter, and emerge in the spring, to pair off for laying the eggs. To quote Professor Lefroy again,—

"The eggs hatch probably within a definite period between two and four weeks; the grub then tunnels inwards, eating the solid wood, usually in the outer sapwood; it feeds the whole summer, rests during the winter, feeds the second summer, and may then become a chrysalis; if so, it becomes a beetle in probably three or four weeks, which rests as an immature beetle and does not emerge till May, two years from the time it was an egg. Under certain conditions, this period of two years may be three, the grub resting over the second winter as a grub, feeding during the next summer, and becoming a chrysalis, and then a beetle only at the end of the third summer.

"Westwood states that the grub feeds for three years, and it may feed longer. But the point to remember is that the egg and chrysalis stage are probably definitely short, while the grub and beetle stage may take a much less definite time, eighteen to thirty-six months for the former, eight to twelve or fifteen months in the latter.

"The only visible stage of the beetle is in its adult form, when it comes out at evening, and all three immature stages are spent entirely in the tree."

Thus it will be seen that the larval stage is very much the longest of the four, and unfortunately it is at this stage, and no other, that the damage is done.

The beetles emerge from the wood rather earlier than those of *Anobium punctatum*, their tapping being most in evidence during the months of April and May, when the pairing instinct begins to assert itself. They are from $\frac{1}{4}$-in. to $\frac{1}{3}$-in. in length, of a medium to dark brown in colour, and have a mottled or spotted appearance on the wing-cases. These spots, which are rather indefinite to the naked eye, are really tiny patches of pale yellowish hairs, which are distributed at intervals over the back of the beetle. The hairs, when highly magnified, are seen to be comparatively thick at the base, tapering gradually to a fine point; each one is set in a depression in the top of a crater-like swelling, and, although not growing very closely together, they are suffi-

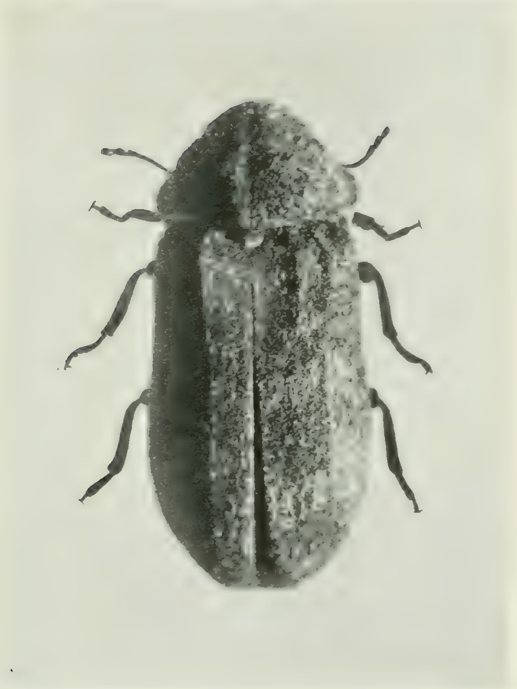


Fig. 19.—The Death-watch Beetle (*Xestobium tessellatum*), magnified nine times.

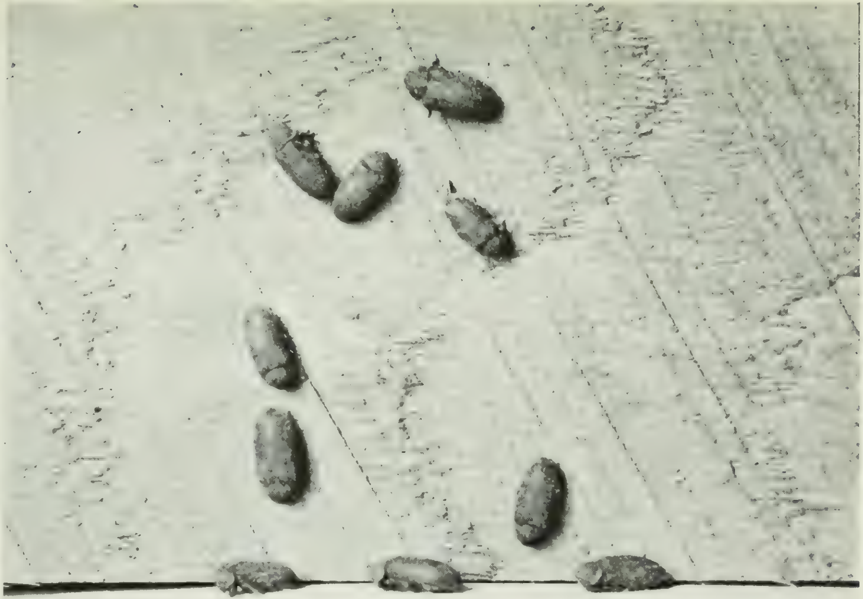


FIG. 20.—Side View of the Death-watch Beetle.

ciently numerous to produce the appearance of faint spots.

Under normal conditions the beetle lives in a wild state, and frequents the dead portions of oak, beech, chestnut, willow, and other trees. It is, however, not often found in coniferous trees, but has been known to infest pine wood which has been fixed in a building for some considerable time. Fig. 19 is an enlarged illustration of the death-watch beetle, in which the mottled appearance can be clearly observed. This illustration differs considerably in shape and markings from that of the common furniture beetle which is seen in Fig 13.

In Fig. 20 a side view of the beetle can be seen, the armoured shape of the head giving it a rather ferocious aspect.

While the destruction that results from the operations of the beetle is more or less obvious after it has emerged from the wood, and the means which it employs for driving its burrows are perfectly well known, the first thing that has to be decided before any definite lines can be laid down for preventing the trouble is how and where it commences, and by what means the insects are able to obtain an entrance to the timber. The difficulty has been somewhat misunderstood in the past, but Professor Maxwell-Lefroy has made three suggestions which probably cover the whole question ; all of these suggestions are quite simple, and the various problems that are raised thereby are of such a straightforward nature that it is comparatively easy, in the light of facts with which we are acquainted to-day, to take precautions against their recurrence, and thus to prevent any further damage, to a very great extent.

The first suggestion, dealing with the origin of an existing attack, is that the original timbers were already infested when they were put in place. This is obviously quite a reasonable hypothesis, as, if only a very small number of grubs were concealed in the timber at the time of fixing, it is certain that under ordinary conditions they would continue to progress until eventually they would arrive at the beetle stage; they would then emerge from the wood, pair, lay their eggs, and the whole business would be started again. The only superficial evidence of the presence of the grubs would be the entrance holes to their tunnels, and these, being very small and in out-of-the-way places, could easily be overlooked. A still more difficult situation would arise, so far as the detection of the danger was concerned, if a number of eggs had been deposited out of sight in a crack in the timber. The result in this case would be exactly the same as in the former one, although its complete development would be somewhat delayed.

Another method of infection which is quite as likely to have occurred is that the grubs were introduced into the building at some period after its construction, when repairs were needed, or when new, but previously infected, timber was used for making alterations to the structure. This method of introduction is practically the same as the first, the only difference being that in the latter case repairs or alterations would not be required for a long time, and the infestation would consequently take place some years later ; thus the damage to the timbers would not reach to such serious proportions until a very much later date.

The third suggestion is that the female beetle flies into the building, either before or after pairing, through a door or window, settles in a suitable place on what has so far been sound timber, and there lays her eggs. For this conjecture to be accurate it must either be a female beetle which is in a condition to produce fertile eggs, or, alternatively, at least one of each sex must be present, so that impregnation can take place on the spot. The former is the more probable of the two. If the infestation arose in this manner, the destruction of the timbers might or might not be deferred to a later date than it would be in the first case, but this could not possibly be ascertained. On the first and third hypotheses, it would be practically impossible to fix any date when the trouble first commenced, unless it could be judged by some extraneous circumstance, but in the case of the introduction of new timber a better estimate could be formed by calculating from the time when the repairs were executed. The estimate would be made a great deal more difficult if the damage was very extensive, as the commencement would be more remote.

Out of the three distinct opportunities that the beetle has to obtain access to a building, the first and second are more likely to have been taken advantage of than the third, as the larvæ may be present unknown in any apparently sound timber all the year round, while the period in which the beetle is capable of flying from place to place is limited to a few short weeks at the most. This is all to the good when preventive measures are being considered, for while no insuperable difficulty exists in avoiding the use of infested timber, or at least in its disinfection before use if desired, it would be a waste of time to attempt to guard against the entrance of such a small creature as the beetle by any of the orthodox means that have been employed in the past for such purposes. Hence, while the introduction of the living grub is the most probable form of infestation judging by the law of averages, the deposition of the eggs has no doubt been the origin of attack in many cases, and it is certainly the more insidious and difficult to guard against. The latest preventive measures for excluding the beetle are more certain and easily applied than any that have been known in the past, and they give promise of a satisfactory solution of the problem.

Considerable speculation has been aroused as to the reasons for the spontaneous termination of an attack when it is known that the timber is infested by larvæ. That the attacks do cease at times without apparent reason is well known, and various theories have been advanced to account for the sudden cessation of activity. It may be that the newly emerged beetles have turned their attentions in another direction in obedience to some instinct, the cause and meaning of which we are not able to elucidate, or the grubs may have perished before the pupation stage, owing to changing conditions of temperature, or to the failure of a suitable food supply. Sometimes in a badly perforated beam, if the outside crust is broken away carefully, numbers of beetles can be found dead in the pupation chambers, but whether they have been unable to bore their way out owing to some physical disability or to the fact that the chamber is too deep below the surface, and have thus perished in the ordinary way, there is nothing to show.

Some reason there must be which causes the attack to cease, and if this reason could be definitely determined, it might be the means of discovering a method by which new timber could be protected against attack in the future.

During the last few years the most searching investigation has been made into the habits of the beetle, and there is no doubt that much has been accomplished towards arresting its progress for the benefit of future generations. The provision of increased light and better ventilation to the dark spaces in which it flourishes has probably materially assisted in exterminating the pests in quite a number of cases. The moist, warm, and stagnant atmosphere in which they seem to thrive best was quite common in buildings of the residential type that were erected several generations ago, as we have already seen in the remarks on dry rot. These unsatisfactory conditions, however, have been considerably modified in the present-day structure ; dampness has been eliminated to a very great extent, except perhaps in the cheaper class of work, and it can be avoided even in this with very little trouble ; and the necessity for an ample supply of fresh air, both for preserving the health of the occupants of the dwelling and for the protection of the structural materials against various forms of decay, is more generally recognised, so that there is probably less opportunity for the beetle to pursue its destructive work with the same chance of success in the newer class of building. The older buildings, however, so many of which are of the most priceless nature, have in only too many instances already suffered such an immense amount of injury, that it is almost beyond the wit of man to devise means that will preserve them intact against utter collapse, without so altering their construction that their historical value would be irretrievably ruined.

The damage that has been caused to the roof of Westminster Hall is probably the most noticeable instance on record, and supplies a very forcible illustration of the devastation that is undoubtedly being wrought in so many of our ancient buildings at the present day by *Xestobium tessellatum.* Special efforts have been made both to arrest the further progress of the attack and to restore the timbers to a safe condition without too much structural alteration, and they have proved so successful, that the methods should be studied by all those who are responsible for the preservation of the almost equally valuable examples of the mediæval craftsman's work which we are still fortunate enough to possess.

A description of the methods that have been adopted for dealing with the roof, and which, it is confidently assumed, have attained the object for which they were devised, contains much that is applicable to any other similar building that is infested with the beetle. This description, together with details of even later methods that are now in use, will be given in the following chapters, while a brief history of the roof itself, and some notes on the structural alterations that had to be made to prevent its collapse, are also appended.

CHAPTER VII

WESTMINSTER HALL

WESTMINSTER HALL is generally considered to be one of the most unique national possessions in the whole world. Its remarkable antiquity for a building of this kind and the important historical associations with which it is invested, raise the Hall far above any other building either in this country or on the Continent, where so many ancient structures are to be found. The veneration which is inspired by this masterpiece is not so much on the score of its great age as on account of the wonderful craftsmanship and cunning that is exhibited in the construction of its roof, and the skill and daring of its designer has called forth perhaps greater admiration than any other example of building construction extant.

Conditions have sadly changed indeed since these noble monuments to the painstaking care and love of craft, which our forefathers were wont to express in terms of wood and stone, were erected, to stand for generations, not merely as specimens of their handiwork, but also as tributes to the stability and excellence of character and the soaring aspirations that were possessed by the nation at large. In those old days—the good old days, as they have rightly been called in many respects—the hewer of wood and the worker in stone wove their very thoughts and feelings into the task upon which they were engaged, not labouring solely for personal gain, but giving of their very best in the effort to produce something that would be worthy of more than a passing notice, and which would endure until the materials out of which it was constructed crumbled into dust. And how well they worked, and with what a keen desire to succeed, can be seen to-day in the numerous wonderful buildings that are scattered throughout the land, many of which are even now in almost as stable a condition as when they were first erected.

To-day the predominating attitude on all sides seems to be the making of profit ; unseemly squabbling on points of little practical importance occur on every hand ; the substitution of inferior materials in place of the very best that can be found, solely for the purpose of cheapening production, has developed almost into a religion ; and the practice of doing or giving as little as possible in return for the greatest benefits that can be secured is rife among all classes, until one speculates as to where it will stop, and what will be the end of it all.

And one may well wonder !

The main part of the Hall itself was commenced by William Rufus about the year 1097, and the walls which he raised are still in existence at the present time. The original roof stood for some 300 years, but in the ordinary course of things it gradually deteriorated and ultimately had to be renewed. This work was carried out by Richard II., who rebuilt it in its present form more than 500 years ago, the walls being first raised somewhat to give the present lofty and imposing appearance which is such a striking feature of the Hall. The roof which now exists, and which has caused so much anxiety of late years, was commenced in 1394, and it was designed and constructed under the direction of the King's master carpenter, one Hugh Herland by name, who devoted all his great ability and consummate skill to the task, in return for the princely wage of 6*s*. per week. About five years were occupied in the rebuilding of the roof, and it was completed in the year 1399. When it is considered what wonderful genius and daring were required to cover a space 65 ft. in width with one single span in the manner that was adopted for Westminster Hall, and that the work was carried out so faithfully and well that it is even now standing, after well over five centuries of use, one cannot but question whether the old time builder was not ahead of his modern representative, at least in the construction of timber roofs.

Sir Frank Baines, Director of His Majesty's Office of Works, paid a very great tribute to the skill by which such marvellous results were obtained, and to the wonderful scientific design and artistry of the timbering, combined with its immense strength, which could hardly be equalled to-day, in spite of the tremendous strides that have been made since that time in mechanical science.

Many of the greatest and most important functions that have been connected with our age-long English history have taken place beneath the roof of Westminster Hall. Coronation banquets were invariably held within its walls amid scenes of the most intense rejoicing, until comparatively recent years ; Bishop Fisher, of Rochester, was tried there for treason ; Laud and the Earl of Strafford were impeached and Cromwell sat in state in the coronation chair beneath the present roof. The trial of King Charles I., which ended at the scaffold, of Byron, Lord George Gordon, and of the seven bishops, were some amongst the many famous cases that were conducted in this, the great national centre of the times, where events, both glorious and tawdry, appear to have been inextricably mixed up for many years. The interminable impeachment of Warren Hastings, which lasted from 1788 to 1795, was another event which reflected little credit on many of the principal actors in the scene. This is but a tithe of the celebrated events which have been staged at Westminster ; a complete list would be too lengthy for inclusion in this volume.

The last important public function that took place in this historic Hall was associated with the heartfelt grief and affliction of the whole nation in mourning. This was the lying in state of King Edward VII., when a national pilgrimage was made by thousands of his loyal and devoted subjects, anxious to pay their last homage and respect to a beloved and popular monarch as they filed past the catafalque.

The history of the events that have taken place in Westminster Hall consists of a strange mixture of brute force trampling on the liberties and freedom of the people and of scenes of the wildest rejoicing that were born of less painful, but not less thrilling, incidents. Many are the crimes against right and justice that it has witnessed, and many are the occasions when right has triumphed over wrong, and when the pent-up feelings of the people have found expression in such scenes as can only be conjured up in moments of the strongest emotion.

The present roof was described in 1923 by Sir John Baird, then First Commissioner of Works, as " unsurpassed as an example of mediæval carpentry and the finest open timber-framed roof in the world." During the 500 years of its existence repairs have been necessitated from time to time on a more or less extensive scale, and, in view of the criticism that has been levelled at the recent introduction of the steel which has been employed to save the timbers against their impending collapse, it is noteworthy that so long ago as 1850 iron ties were employed, at the instance of Sir Charles Barry, for strengthening the roof. These measures have also been freely criticised. Repairs were undertaken in 1663, when the roof was rather more than 250 years old, while in 1747, and again in 1821, further attention was needed, the intervals between the strengthening operations being roughly eighty years in each case.

The following description of the state of the roof, and the work that was carried out in the latter year, is taken from the *Observer*, dated April 23rd, 1821, and is interesting when it is compared with the very extensive repairs that have been necessitated by the action of the death-watch beetle, and which have lately been completed by the Office of Works :—

> "THE CORONATION
>
> "The great alterations now carrying on in Westminster Hall by the Board of Works are in the repairs of the ancient roof, many parts of which, upon perforating the timber for suspending the chandeliers for the Coronation, were found so rotten that the safety of this noble roof, which, for mechanism and antiquity, has become so justly celebrated, required an immediate separation of the decayed parts, and the fitting in of substantial joinings to complete the framework. A general survey of the roof lately took place in consequence of the discovery of this decay, and the oak (which, according to the popular tradition, was first imported by William Rufus) was found mostly sound, but the cherry-tree rafters were worm-eaten. They have been in consequence all taken down and renewed.
>
> "It was deemed right in the progress of the work to take down the old lanthorn, which illuminated the Hall from the top of the roof. Its weight was found to have made an impression on the roof, and the taking it down was a difficult and rather perilous work, from the enormous quantity of lead which was clumsily used in its original manufacture."

After this brief memorandum was written, nearly a century was added to the age of the roof without any apprehensions as to its safety, but, as could only be expected, the timbers, already badly worm-eaten in places, showed serious indications of further damage. As a consequence a considerable amount of repair work to the roof has been carried out during the last ten years, far surpassing all previous operations both in extent and also in the time that was occupied in its execution. Before the repairs were commenced the matter was considered to be so important, and of so urgent a nature, that a Blue Book was issued by the Government entitled "On the Condition of the Roof Timbers of Westminster Hall, with Suggestions for maintaining the Stability of the Roof"; this was in 1914. The book contained a comprehensive report by Mr. Frank Baines on the state of the roof as it was at the date of examination ; explained the cause and effects of the damage that had been done, and which was still going on ; and set forth in detail certain measures which it was essential should be put in hand to retrieve the position and avert a national disaster.

Some years previous to the publication of his report, Mr. Baines—now Sir Frank Baines—discovered that the most serious and extensive deterioration was going on in various parts of the roof, and it was decided that a thorough and systematic examination of the timbers was urgently needed to determine the nature and extent of the repairs that were necessary if the collapse of at least four out of the thirteen trusses was to be avoided. It was not possible to make more than a cursory examination at the time, as, the height of the roof from floor to ridge being more than 90 ft., it was difficult to get at. To solve the problem, and for convenience in the prospective operations, a substantial scaffolding was erected, so that the investigation should be as thorough as possible, and every portion of the timber and stone work was scrutinised with the greatest care.

The report—to which reference has been made—discussed various possible causes of decay, and reviewed each one in relation to the matter under consideration ; the responsibility for the widespread damage that the roof had sustained and the movements that had taken place in the ribs and beams was placed on the shoulders of the death-watch beetle. A great deal of consternation was engendered in the mind of the public by the possible impending destruction of this justly celebrated example of the carpenter's art, and the beetle was endowed with such an unenviable notoriety that its name became almost a household word for quite a long time. Most of this natural anxiety has evaporated since the roof has been strengthened, but it is safe to say that the emergency that arose was the means of creating serious misgivings in many quarters, and similar examinations were made in a good many of the older buildings, with in more than one case the same results. It certainly impressed the dangers of delay on the minds of those who were responsible for the safety of these ancient monuments, both public and private, but who had up till then been quite content to let things take their own course, under the impression that, as nothing had occurred to give cause for alarm, the situation did not demand any particular attention. This was no doubt due, not to culpable neglect, but more to the widespread ignorance on the subject that prevailed.

It was stated in the report that the particular species of beetle that was under consideration—*i.e.*, *Xestobium tessellatum*—is rarely found in any other kind of timber but oak, and that it is so persistent in its work when once it is fairly established in the wood that the fact of its being infested is apt to give rise to a despairing frame of mind in those who are familiar with the habits of the beetle and the wholesale destruction of which it is the author. As an illustration of the boring powers of the insect, some of the larvæ were collected, and were securely corked in a test tube, together with a section of the timber in which they were found. Within four days one of the larvæ had left the section of wood and had bored its way completely out of the tube by tunnelling through the cork. The larva could be plainly observed at its work, and the speed with which it made its escape was almost incredible. It is of course obvious that a much longer time would be occupied by the insects in boring through oak, and this fact was pointed out, but that their energy in attack is quite amazing was proved by the observations that were made.

A full and detailed summary of the condition of the roof, so far as had then been ascertained, was included in the Blue Book, practically every timber being mentioned, and its condition minutely described, while exhaustive details and drawings, which showed the damage that had been sustained by the trusses and bays, were reproduced. It was found during the examination that the hammer-beams, on which the strength and cohesion of the structure very largely depended, had in nearly every case dropped at the inner end—*i.e.*, the end farthest from the wall—this being due to the superimposed weight of the hammer-post above, which carries the main collar-beam and the whole of the upper portion of the roof. As the hammer-beams operate mainly as cantilevers, they had become specially dangerous owing to the decay, but, in addition to this, it was discovered that in three cases the beams had been actually cut across with a saw at a point several feet from the wall, and had been pieced up with modern oak at some time previous, the date of which could not be ascertained ; they were thus completely unable to function as cantilever supports, and one of them was so loose that it could actually be shaken by the hand, and was therefore dependent for its stability on the remaining timbers, which it should have been supporting instead. The seriousness of the position which existed will no doubt be realised when it is stated that the hammer-beams project about 18 ft. from the masonry, and that each one supports a weight somewhere in the region of 15 tons at the foot of the hammer-post, the point of intersection between the post and beam being 15 ft. distant from the wall.

Very extensive damage had been caused to the hammer-beams by the grubs, the timber being in almost every case badly decayed, generally at the centre. Large cavities were found at the foot of the lower principal, and the beams had been reduced to a mere shell at the very position where the greatest stress would occur ; these cavities had been blocked up at some time or other by driving pieces of new oak in from the wall side, but the fresh timber had in turn been attacked, showing that the larvæ were still actively engaged at their work. Cast iron shoes had been put in—probably by Barry—to receive the defective wall ends of the hammer-beams, but in nearly every case they were tilted either inwards, due to the pull of the tie rods that were inserted from the shoes to the hammer-post, or outwards, by the thrust from the weight of the roof itself.

The sectional dimensions of the hammer-beams are 1 ft. 9 ins. by 1 ft. 10½ ins., and of the hammer-posts 3 ft. 2½ ins. by 2 ft. ¼ in., the remainder of the timbers being in proportion. The decay had mostly occurred round the mortices for the tenons in the bottom of the post, and only when the centre had been completely destroyed did surface decay appear to any serious extent. This is quite in accordance with what has been written as to the habits of the insect, as, while the grub works inside the timber for from two to three years, it is quite a simple matter for the beetle to eat its way out, leaving a comparatively small hole as evidence of what has been going on within. Many of the other members of the roof had been repaired in a very rough and ready fashion by cutting out the decayed portion and fitting new pieces of oak into the place, but the work appeared to have been done in a very ineffective manner, and gave cause for wonder as to why the whole roof had not given way under its own weight long before.

A situation such as this called for the most drastic steps before the cause for anxiety could be removed, and it was essential that whatever remedy was proposed should be put into execution quickly, or the most serious consequences would have ensued. The damage, however, that had been inflicted by the beetle, was so extensive, and in such extremely awkward positions compared with the means of access to the roof, that it was out of the question to attempt any remedy by replacing the decayed portions with fresh timber, as this would have entailed the removal of a large portion, if not most, of the roof. In addition to this, it was of the highest importance that as much of the old timber as possible should be preserved intact, as the sentimental value of the roof would be largely destroyed if any great addition of new material were made.

The decision at which Mr. Baines ultimately arrived was to employ steel for strengthening the trusses ; this did not meet with unqualified approval from those whose æsthetic tastes appeared to be outraged by such apparent vandalism, but as no other satisfactory method of ensuring permanent safety to the roof was forthcoming, the original suggestions, as outlined in the report, were put in hand in 1914.

Mr. Baines explained the position by describing the existing conditions, and laid down his suggestions for overcoming the danger of collapse. He also pointed out the risk that would be involved if any attempt were made to patch up the damage, and he put the question into a nutshell in the following statement, which left very little room for any alternative proposal :—

> " To maintain the roof in its integrity by a full scheme of steel reinforcement, designed so as to affect the appearance of the structure as little as possible, and to afford adequate support to every one of the members. The particulars of this scheme will be developed later, but its bearing on this portion of the report is that, should some such scheme not be approved, not only will it be impossible to render the roof safe by piecing up the timbers, but it might even be necessary in certain cases to take the whole of some of the trusses down, renewing in their entirety many of the constructional members. It will be realised that the gravest danger would be involved in merely cutting and piecing up many of these defective members, as their whole effectivity is relative to their being complete members in themselves, and not jointed members. To cut and piece up the hammer-beams would be the gravest of constructional errors, should they be called upon to carry unrelieved the present stresses of the roof. I am therefore of opinion that by agreeing in principle to some system of

> steel reinforcement the whole of the timbers examined up to the present may be so treated that every vestige of the original wood unaffected by decay can be retained, and that only certain portions, such as entirely perished purlines, would have to be wholly renewed.
>
> " Should the principle here outlined not be adopted, I would not advise the Board to attempt to secure the roof by only piecing up the defective members. It would, in my opinion, be absolutely necessary to renew wholly a great many of the main structural members, which would involve such an enormous rearrangement of the roof that it is doubtful whether the result when completed would be of any historical value."

The situation thus stated succinctly, and without any beating about the bush, had to be faced. The absolute urgency of the position could not be questioned, and, in the face of such definite statements from an expert who had had the opportunity of investigating the position at close quarters, it did not seem to be possible to restore the roof to a safe condition by the employment of wood alone and at the same time to preserve its original features as one of the most priceless national possessions of its kind in the world. As no one came forward with a better or more reliable method that could be guaranteed to endure permanently, the restoration was ultimately carried out by the Office of Works on the lines suggested by Mr. Baines.

Exceptional perseverance was required in making good the defective portions of the timbers and in providing against any possibility of collapse in the future ; no less than ten years were occupied in doing the work, but eventually success attended the efforts that had been put forth for so long, and the whole of the roof was made secure.

When the report was drawn up, it was roughly estimated that by following the plan laid out in the suggestions not more than about 35 to 40 per cent. of the timbers would have to be renewed, this rather disquieting proportion being due entirely to the widespread nature of the decay ; failing the assistance of the steel reinforcement, however, something like 70, or even 80, per cent. would need replacement, owing to the fact that certain important members were so badly perished at the joints and ends that they were unable to support their burden for very much longer. By introducing the steel ties and plates the timbers would be relieved from the stresses that were set up in the roof, and would therefore not need such drastic treatment.

It was also stated that every attempt would be made to preserve all of the original moulded work, and that the faces of the various members would be left unaltered as far as possible, so that the disfiguring appearance of a large number of patches of new timber would be obviated. The walls and foundations were in a good condition, and likely to be able to withstand any of the dead loads or thrusting stresses which they might be called upon to bear.

The principal considerations which had to be borne in mind when designing and fixing the steel reinforcement were summarised as follows :—

"1. The steelwork should be so designed as not to prejudice seriously the appearance of the truss and the general amenities of the structure.

"2. The steelwork should in itself be adequate, not only to carry effectually the weight of the trusses, but to support each main member so that it can be pieced up where decayed, rather than entirely removed.

"3. It should be designed so that too great a thrusting stress is not transferred to the walls.

"4. It should, when inserted, fully provide against the possibility of collapse in any of the trusses, should further dangerous decay take place."

The actual method of reinforcing the roof that was eventually adopted and carried out with complete success was the provision of steel trusses which, following as nearly as possible the outlines of the existing roof, were to support the weight, while at the same time they were to be so carefully hidden from view as to be, to all intents and purposes, invisible from the floor of the hall.

The insertion of the new trusses and the repair of the damaged woodwork was a most delicate matter, and it needed the utmost skill and patience to carry the various operations through in safety. About 270 tons of steel altogether were used for the reinforcement, while the decayed portions of the timber were patched with specially selected oak that was grown at Wadhurst Forest, in Kent, a variety that is noted for its great strength. It is interesting to note in this connection that the oak was used as soon as possible after the tree had been felled, no seasoning or preservative treatment of any kind being employed. In the case of one tree in particular not more than three months divided the period when it was standing in the forest from the time that it was built into its place in the roof. No time was lost in attempting to produce an antique colour or appearance on the new oak by artificial means, so that it should match the old timbers, but, although there is naturally a distinct contrast between the two, the difference is not particularly conspicuous when looking up from the floor, as, owing to its great height and the lack of illumination, the roof space is, as a rule, but dimly lighted.

The restoration was completed in 1923, and the great Hall, which had necessarily been closed while the work was in progress, was reopened by the King and Queen with great ceremony. In the course of his speech in reply to an address by the First Commissioner of Works, His Majesty emphasised the fact that—

> " Westminster Hall appeals in a special manner to the mind and imagination of the whole English-speaking race. For centuries it has witnessed the growth of the Constitution, and has been, as it were, a link between the Crown and the people. In far-off days it was the great hall of the King's palace, and more recently the seat of the highest law-courts of the kingdom.
>
> " In common with all lovers of ancient and historic buildings, I wish to express my warm thanks and congratulations to the Ancient Monuments Board, the Director of Works and his staff, and to all the workmen engaged upon the restoration for their skill and untiring, devoted labours, which have co-operated towards so successful an achievement. Much of their work is hidden from the public eye ; nevertheless to them be the credit for having given, I sincerely trust, centuries of new life to this masterpiece of British architecture."

Sir John Baird, who was the First Commissioner of Works at the time, stated in his address that the scheme of preservation had aimed at retaining as much as possible of the original timber, and that this had been accomplished by the insertion of a braced steel frame, practically invisible from the floor of the Hall. Slightly less than 10 per cent. of new oak had been used for the essential repairs of decayed beams and posts, and the authorities who were responsible for the work felt confident that they had been successful in giving the roof a long new lease of life while completely preserving its character. The reduction of the preliminary estimate of 35 to 40 per cent. of new timber that would be needed, down to as little as 10 per cent., is particularly gratifying, as it means that the character of the roof is altered considerably less than was anticipated. The very greatest credit is due to the Office of Works for the wonderful manner in which the restoration has been carried out. An illustration of the roof is given in Fig. 21.

It must not be forgotten, however, that the very extensive structural alterations and repairs that were put into effect merely represented the precautionary measures that were essential to preserve the roof in the condition in which it was at the time of examination. This, however, was only a part of the measures that were required, for it was known that the beetle, the cause of all the anxiety and expense, was still steadily pursuing its work, as numbers of the grubs had been discovered and collected for experimental purposes. It would thus only have been a matter of time before the timbers would have been totally destroyed beyond the possibility of further treatment, and it was necessary that a limit should be placed on the beetle's activities. Thus another problem of but little less importance than the structural one was presented for solution.

How the problem was solved, so that the energies of the beetle were circumvented and the larvæ destroyed, will be described in the next chapter.

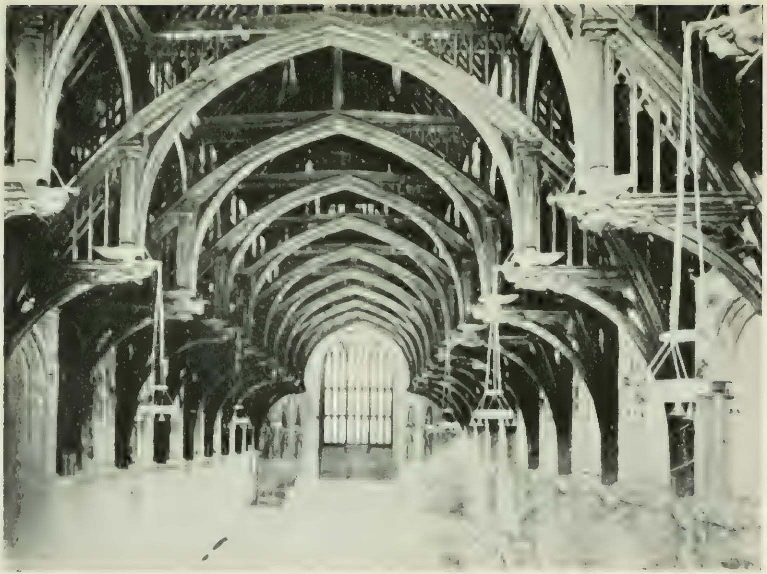


FIG. 21.—Westminster Hall Roof.

CHAPTER VIII

THE DESTRUCTION OF THE BEETLE

IN any discussion of the problem of how best to destroy the death-watch beetle and its larvæ, the situation is rendered much more difficult by the fact of the insects being entirely concealed from view inside the timber. In most of the attacks from living creatures to which timber is exposed, some sign or other of the enemy can be seen on, or independently of, the surface, as each one usually commences operations on the exterior of the wood and leaves well-defined indications of its presence. This applies to the depredations of the white ant, the *Teredo navalis*, or ship worm, the grubs of various moths, and also to the still more malignant and wide-spread disease dry rot. As, however, the eggs of the beetle are laid and hatched in the joints and crevices of the timber, where they are completely out of sight, the grub starts on its mission with the very material advantage that not the least sign of its presence is visible, and by the time it emerges from the wood in the form of a beetle the damage has been done, its mission is practically ended, and very little remains for it but to die an inglorious death.

It goes without saying that any method of dealing with the problem to be successful must be capable of destroying, not only the beetle itself, which is rather elusive, but also the larvæ and the eggs as well, and as both of the latter are situated in a less accessible position than the former, the difficulty is intensified in their case. In addition to this, it is not often possible to ascertain correctly the extent of the damage which the timber may have sustained, or whether it has really suffered any damage at all, without going to a great deal of trouble and maybe expense. This, of course, does not apply to timber in the last stage of decay.

As a rule, a very good idea can be gathered as to the soundness or otherwise of a beam by tapping the wood sharply in different places with a hammer; normally it should give forth a clear, ringing sound, and the hammer should recoil after the stroke, especially in the hardwood varieties, but if the interior is burrowed to any great extent, the sound will either be more or less muffled and dead, or it will give out a hollow boom, in which case no doubt as to the necessity for a closer investigation need be entertained. Those portions of the timber which give cause for suspicion, either on account of the doubtful quality of the ring or from the presence of exit holes at intervals on the surface, should be further tested by driving a gimlet into the wood as deeply as possible and judging of the condition of the timber by the ease with which the gimlet enters, or by the appearance and condition of the borings which are brought out when the gimlet is withdrawn.

All timbers in out-of-the-way places, such as in the roofs of ancient buildings, the hidden portion of the floors, and the larger constructional members upon which the stability of the structure depends to any extent, should be examined now and again, so that any approaching danger from the attack of the beetle or of dry rot can be detected and suitably dealt with at once. Hardwoods especially need careful watching after they have reached a fair age. This does not necessitate a very frequent inspection so far as the beetle is concerned, as the process of disintegration is so slow that many years must elapse before the timber becomes riddled so much as to be in danger of falling. Exit holes should be specially watched, and as soon as they appear each one should be marked and note taken of any more as and when they are made. The necessity for occasional inspection is clearly shown by the experience that has been gained with the roof of Westminster Hall. This is supposed to have been first attacked centuries ago, and but for the systematic examination that took place in 1913 the whole structure might have collapsed utterly at any moment, and the roof would have been lost for all time. If a suitable treatment for the destruction of the larvæ had been instituted soon after the attack commenced, all the repairs that have lately been carried out would have been avoided. It is probable, however, that no means of attaining this highly desirable object were available at the time.

It must not be supposed that an effective method of exterminating the beetle from the roof of the Hall was discovered without any trouble. Far from this, the problem seemed to be almost insuperable in the early stages of the work, owing to the immense size of the affected timbers and the widespread damage which they had sustained. And, to make the difficulty still more acute, the historical value of the roof was so considerable, and could so easily be destroyed, that the very greatest caution had to be observed both in the destruction of the insects and in the restoration of the timbers, or further damage would be inflicted. How well this difficult and delicate operation has been carried out was described in the last chapter, while the extent to which the steps that were taken for the permanent extermination of the beetle have been successful will be shown more positively as time goes on. It is practically certain at the present time that the treatment has had the desired effect, and that all life has been destroyed.

The credit for the preparation of the solution that was employed for dealing with the beetle is due to Professor Maxwell-Lefroy, who studied the question closely in all its aspects before deciding on the most appropriate remedy that could be adopted.

The problem of the extermination of the larvæ that are already in the wood is closely bound up with that of the exclusion of the next generation of beetles, as it would be merely beating the air to destroy the existing larvæ and then to permit a fresh relay to take their place immediately afterwards. Old roofs that may have been infested many years ago will doubtless require more or less extensive attention or repairs, and alterations may be needed quite apart from deterioration from this or any other cause. In either case the employment of fresh timber will often be imperative to make good the defects, or to effect some improvement or other, and it is to the new timber that the closest scrutiny should be given before it is used, so that it can be decided with certainty that it does not contain either eggs, living grubs, or beetles. Many ancient and valuable roofs have been infected in this manner in past years owing to neglect or oversight in this respect, but it is not altogether inexcusable, as little was known of the insect or its habits up to comparatively recent years.

When new timber is employed, it is difficult to detect the presence of eggs without the very closest inspection ; larvæ or pupæ can be found more easily, as the entrance or exit holes are clearly visible. The eggs, being so small, can only be discovered by subjecting the timber to a most searching examination, and even then many of them are sure to escape the keenest eye, as they will be quite out of sight in some crack or other.

The safest method by which the situation can be met is by subjecting every piece of timber or other material to a thorough disinfection of some kind before it is built into the roof, the treatment being carried out after the timber has been shaped and before it is allowed to come into contact with any portion of the existing woodwork.

Unfortunately this comparatively simple operation is not, as a rule, practicable, as a totally different problem is usually presented, which, consisting as it does of how best to get rid of the beetle in an existing structure, is infinitely more difficult and costly, and can only be surmounted with a great deal of trouble.

The roof is the portion of the building which is most frequently damaged, as it is not often that facilities for its examination are available, and the attack is therefore allowed to continue without hindrance ; the floors and other internal woodwork very often suffer the same fate, but being more in the public eye, so to speak, the trouble can be detected at an earlier stage. The problem that is presented in dealing with timber *in situ* arises on account of the difficulty that is experienced in obtaining free access to every portion, so that a really effective process can be carried out, and as the timber is not so open to investigation, the treatment may degenerate into a purely superficial one, unless very great care is taken to see that penetration to the centre of the wood is complete ; thus the treatment is more or less limited to those places that are least liable to attack. The beetle is of rather a retiring disposition, and prefers those out-of-the-way situations where darkness reigns, and this is perhaps naturally the most inaccessible portion of the whole building.

The death-watch beetle has, of course, been quite familiar as a name to the general public for many years, but its reputation has been attained mainly on account of the foolish superstition that even yet clings to the tapping noise it makes. Very little definite knowledge as to its history and habits appears to have been gathered until comparatively recent years, and the widespread nature of its attack, which is now quite a familiar feature in old oak roofs, was unthought of until the serious condition of the roof of Westminster Hall was discovered twelve years ago.

The report on this roof, which has already been discussed in Chapter VII., spread consternation in the minds of those who were responsible for the safety of the many historic buildings in the country, with the result that investigations were instituted all round, and it was found that nearly all the most important buildings were in some degree or other infested with the pest, and that in many cases immediate measures were necessary if disaster was to be averted. Since then much water has flowed under London Bridge, and a great deal of valuable information has been obtained as to the method of dealing with infested timber, so that as long as the structure is not actually in a dangerous condition and liable to collapse, the beetle can be exterminated at a reasonable expenditure of time and money, and no apprehension need be felt as to any further resumption of the attack.

Timber can be treated for the destruction of eggs or larvæ in a variety of ways before it is fixed. Heat can be applied in specially constructed chambers, the temperature being raised to about 130° Fahr., until it has penetrated to the centre of the log. This will not cause any injury, as timber is capable of withstanding a temperature up to 250° Fahr. without damage ; anything higher than this must not be applied, as it would cause the fibres to become brittle, and much of the strength would be lost. It is obviously impossible, however, for this treatment to be employed for a roof or floor, so that it cannot be considered as a remedy for an existing attack.

Fumigation, too, is perfectly effective, provided that the insects can be subjected to its effects, but this also is impossible in the circumstances under consideration.

The impregnation of the timber with a poisonous liquid solution would be a reliable method of destroying the beetle, larvæ and eggs, if absolute penetration to every part of the timber could be ensured, but this method is not to be recommended on account of the prohibitive expense of the treatment and the practical impossibility of injecting the solution through the sounder portions of the timber without pressure being employed. No difficulty would exist in forcing a solution to penetrate through the system of tunnels that comprises the field of operations of the grub, provided that the inlet or outlet holes were accessible, but even then it might not actually reach the insects in isolated burrows, as the beetle which made the hole would probably have flown away, and the grubs would not be exposed to any attempts that were made to dislodge them by way of the other burrows. They would thus be left alive to pursue their work unmolested. In a very bad attack, in which the burrows were quite close together, the solution would be enabled to penetrate and soak through the timber with good results.

It should be recognised that any treatment to be really satisfactory must not only destroy the existing insects at the moment, but its effects must persist for some considerable time, so that any further attack would be rendered abortive and protection assured for the future.

When the report on the roof of Westminster Hall was made by Mr. Frank Baines, it was at once realised that two problems were presented for solution, both of which were specially urgent, and both of which possessed exceptionally difficult features. The strengthening and repair of the roof itself needed to be carried out with the greatest skill and circumspection, so that it could not only be made safe against the collapse which threatened at any moment, but that it should also be preserved intact as far as possible without impairing its sentimental value. This was the mechanical difficulty that was faced and overcome by His Majesty's Office of Works.

The second problem, which was probably the more troublesome of the two, as so little was then known on the subject, was the destruction of the beetle and the prevention of further decay. Much thought and investigation was devoted to the matter by Professor Maxwell-Lefroy, who was assisted by experts on the chemical side of the question, and ultimately he arrived at a decision as to the best method that could be employed to stop the trouble and to prevent its future recurrence.

During the original investigations into treatment by a liquid solution, sixteen points were aimed at, all of which, it was considered, should be combined in any system of treatment that might be adopted. The principal qualifications can be summarised as follows :—

1. The solution should penetrate deeply into the timber without the necessity for the application of mechanical pressure or the use of expensive apparatus.

2. It should give off a vapour that would permeate the whole of the crevices and burrows in the timber and prove destructiv to the insects within.

3. It should leave a permanent deposit on the surface of the timber that would be poisonous to the beetle on its emergence and to the eggs if any should be deposited in the crevices.

Minor points were that it should not be unduly inflammable nor yet of an aqueous nature, and should not give off an unpleasant odour, neither should it be dangerous to human life either during its application or at any subsequent time. It should also be simple to use, and to be procured cheaply.

The first antidote that was tried was on the following lines :—

Tetrachlorethane	50 per cent.
Cedarwood oil	6 ,,
Solvent soap	2 ,,
Paraffin wax	2 ,,
Trichlorethylene	40 ,,

This was employed for some time, and was found to be a very good insecticide, but it was such a virulent poison, and its toxic effects on the workmen who were employed in its application were so pronounced, that its use had to be discontinued.

An alternative mixture was afterwards arrived at which, while complying with all the requisite conditions, did not possess the objectionable properties of the first solution. It was composed of—

Dichlorbenzene	92 per cent.
Soap	3 ,,
Paraffin wax	3 ,,
Cedarwood oil	2 ,,

This solution was employed generally for the disinfection of the roof ; the liquid was sprayed liberally over all the surfaces of the timbers twice, so that as deep penetration as possible could be obtained. The soap, being made with metallic elements such as barium, zinc, etc., constituted the poisonous ingredient in the mixture, while the paraffin wax produced a very thin film that was changeless, preventing the evaporation of the dichlorbenzene, holding down the soap and coating the eggs. The dichlorbenzene gives off a strong vapour, which diffuses through the burrows and destroys the larvæ. The cedarwood oil, being distasteful to the beetles, was introduced to prevent the possibility of the reinfection of the treated parts from other portions of the roof, as the work had necessarily to be carried out in separate sections.

Later on a different solution was suggested, in which the place of the dichlorbenzene was taken by zinc or barium oleate, with 83 per cent. of water to act as a vehicle, some alteration also being made in the proportions of the remaining ingredients. This liquid was to be either brushed or sprayed on to the surfaces of wood, so that a coating of the wax, soap, and metallic oleate would be left, and this, while being invisible and not directly affecting the colour of the timber, would remain as a permanently poisonous film that had no objectionable effects on the human body. The weak point in this solution was its water content, which, it was urged, would produce disastrous effects on the timber.

Bichloride of mercury dissolved in spirit had frequently been used for destroying the insects previously to this, but the harmful effects which it exerted on any one who might come into contact with the treated surface were so dangerous that it had to be relinquished.

In the treatment of roofs the objection to a poisonous material is not particularly important so long as it can safely be used by the workmen, but when the mixture is applied to the woodwork nearer the floor, such as panelling and partitions, more care is needed, as it may frequently come into contact with the bare hands or the clothing of people who may be using the building.

The foregoing formulæ of the solutions that were actually used or recommended in the early stages of the work at Westminster Hall are quoted as indicating the various stages which have been passed through in the experimental research that has been so untiringly devoted to the subject. Each of these mixtures has now been discontinued in favour of a simpler and cheaper, yet even more effective, solution that has recently been invented by Professor Lefroy, who has been good enough to impart his latest formula to the writer and to explain its superiority on various grounds. The solution which is now advocated is really a variant of that given on p. 180, and consists of—

Dichlorbenzene	50 per cent.
Mineral oil	47 "
Barium oleate	3 "

In this mixture the dichlorbenzene constitutes the volatile portion of the solution, being converted into a vapour which penetrates completely through the tunnel system and destroys all the grubs with which it comes into contact. Penetrating power is provided for the liquid by the mineral oil, which is most effective as a vehicle (the manner in which ordinary paraffin will "creep" through timber is well known), and which can be purchased for about 1*s*. per gallon. A refined thick oil is used for the purpose. The barium oleate supersedes the soap, wax and cedarwood oil in the previous formula, and as it sets into a very thin film which, while being quite invisible, is a deadly poison to insects, although harmless to human beings, it answers exactly the same purpose at less cost.

The manner in which this solution operates is quite automatic after it has been distributed over the surface. The mineral oil soaks deeply into the timber, carrying the dichlorbenzene with it; the latter is then liberated in the form of a vapour, which penetrates to the farthest recesses of the burrow system and destroys the grubs. The barium oleate performs the most important function of preventing reinfection at any future date, as the film, which persists almost indefinitely, is offensive and poisonous to any grubs which may be incubated from freshly deposited eggs, and thus prevents their entrance to the timber. At the same time, if any grub or pupa that may be in the timber should by any chance escape the attentions of the dichlorbenzene vapour, and should succeed in passing into its final stage as a beetle, it is destroyed by the poisonous film through which it has to bore as soon as it attempts to eat its way out of the wood. Thus every possible contingency, whether the ingress or the egress of the larvæ or beetles, appears to have been provided against by this comparatively simple remedy, which is quite easily applied and inexpensive to prepare.

If the fluid is distributed with a proper spraying machine, it is calculated to cover from 20 to 30 square yards to the gallon, and its application can be effected so rapidly that an ordinary church roof can be sprayed in a day—apart from any structural repairs that may be necessary—at a total cost of not more than approximately £50. The expense of providing the necessary scaffolding is, of course, an additional item, the cost of which will depend entirely on local conditions.

Any liquid that is used on timber in accessible positions should be non-poisonous, non-inflammable, and not irritant. There are at least five preparations on the market that conform to these requirements, and they can be purchased ready for use at a cost of from 10*s*. per gallon and upwards.

When the immense historical and architectural value of so many of our mediæval roofs is taken into consideration, the advantages that are possessed by such a simple, yet effective, remedy for certain disaster will easily be appreciated. The introduction of old timber from one building to another for structural repairs, or of any timber that may conceivably be infested with either eggs or larvæ, should be strictly guarded against, as, although the efficacy of any treatment that is adopted may be such as to give protection against either internal or external insect life, at the same time it is most desirable to take all precautions against any possible chance of trouble later on.

As an instance of the deplorable results that may spring from the neglect to give attention in the early stages of the disease the case of Peterborough Cathedral may be given. For some years past the masonry of the cathedral has been undergoing restoration, the cost of which will run into many thousands of pounds. Funds to liquidate the debt have only been obtained with difficulty by public subscription. Now, to quote from the public appeal for further assistance which was issued in September, 1924,

> " it has quite recently been ascertained that throughout the building the *vast roof spaces are in possession of an abominable beetle*, the grub of which in innumerable hosts is steadily and rapidly eating away beam after beam and strut after strut above the painted and plain ceilings of the choir and the nave and transepts. . . . The result of the examination is that *the damage done by the beetle will cost* £10,000 *to set right*."

This sum, although formidable in itself, is small compared with the £100,000 which has been spent in getting rid of the beetle in Westminster Hall, where the roof is less than half the size, and in repairing the damage that has been wrought, and it does not seem to be an excessive amount in comparison with " the manifold and inestimable worth of such a cathedral as this."

In a leaflet that has been published by the Society of Antiquaries of London, certain directions are given by which the condition of any oak roof or structure can be deduced, so that it can either be left untouched with confidence as to its soundness, or, if the attack be in an early stage, it can be treated at small cost. This leaflet states :—

> " The attack of the beetle will be found specially in places which are ill ventilated : wall-plates, purlins, the ends of principal or common rafters in walls are likely places, as also are spots where a number of timbers come together ; the open well-

ventilated tie-beams or hammer-beams are not so likely to be attacked unless they are very large.

" It is important to look for any wood added during restoration or repair, as so many buildings have been attacked in this way, and if there is a definite record of restoration or repair in oak during the last century, it is almost certain that attack will now be in progress."

A comparison is drawn between the size of the exit holes that are made by the furniture and the death-watch beetles respectively, and it states that the furniture beetle is of no importance in oak, although it is sometimes found in the sapwood at the edge of the timber, and that, although it is common in deal and other softwoods, it rarely goes so far as to render a timber unsafe.

The instructions for determining the approximate time when the attack commenced may be of assistance. They state :—

> " If the larger holes are found, they should be examined carefully to see if they are fresh and clean-cut ; if so, they may be recent, and active attack may be expected to be in progress ; but if they are of the same colour as the surface, with dirty edges, they are probably old and not significant of present attack. Of course, in long-standing attack both will be found.
>
> " A second point to look for is the characteristic oval buff-coloured pellets which are the excreta of the grubs. If these are continually falling, or if fresh heaps of them are found below fresh holes, it may be anticipated that attack is in progress. Several cases of inaccessible roofs have become suspect on account of the constant dropping of these pellets, and examination has shown them to be attacked now. The pellets are absolutely diagnostic of this grub "

The actual size of the exit holes that are made by the death-watch beetle is shown in Fig. 22, and a heap of freshly discharged pellets is also shown, indicating that an attack is in progress.

The directions quoted from the Society's leaflet

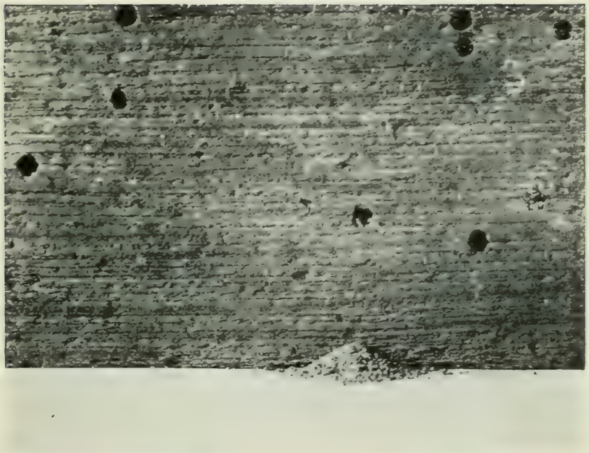


FIG. 22.—Exit Holes made by the Death-watch Beetle (natural size).
Reproduced by the courtesy of the Society of Antiquaries of London.

should be carefully noted by all those who are interested in the subject of the death-watch beetle, as they may be of the greatest assistance in deciding doubtful cases, and may be the means of either saving valuable property by indicating the necessity for the immediate treatment of the woodwork, or they may be instrumental in avoiding unnecessary expense through taking active steps when the timber is not really infested with the grub.

Certain difficulties may arise at times as to the best method of effectually dealing with all the surfaces of the timbers when they are in such close proximity to each other that access to every portion can only be obtained at considerable expense. This matter will have to be decided on the spot, as the question is a mechanical one, and consists merely of the provision of a convenient avenue of approach to the various timbers.

A somewhat similar difficulty may also be experienced when the attack is situated in beams of such a large sectional area that the spraying liquid is unable to soak in deeply enough to permeate the whole timber. Where beams of very large dimensions are concerned, successful penetration can often be ensured, or at least assisted, by boring a hole in the timber at a place where the burrows are believed to be the most numerous, driving a short length of iron pipe into the hole to which the nozzle of a force-pump is securely attached, and pumping the liquid in under as much pressure as can be developed with the apparatus that is available. In a very badly infested beam the liquid could be forced completely through the tunnel system by this method, destroying all larvæ, pupæ, or beetles in its progress, and the wood could thus be thoroughly saturated as a preventive against any further attack. If the attack had not progressed to a serious stage, the method could still be adopted with advantage, holes being bored at different intervals according to the estimated position of the burrows. Thus the penetration of the liquid would be much more thorough than could be obtained by the mere spraying of the surfaces, and, in conjunction with the latter process, would provide ample protection against a recrudescence of the trouble. The least damage would be caused to the beam from loss of strength if the holes were bored on the line of the neutral axis. If this were not possible, they could be bored a little above the line without risk of weakening the timber too much, as the upper part of the beam would be in compression ; the liquid would also penetrate to the lower half of the beam more readily by gravitation. Half an inch would be a suitable size for the holes.

With timber that is in a comparatively sound condition it would be an advantage, in the absence of burrows, to place the holes so that they connected directly into a large shake on the upper side of the beam, as the liquid would naturally follow the line of the shake, and better distribution would be assured.

The possibility of introducing a liquid that would assist in strengthening a badly decayed beam at the same time as it destroyed the grubs in the interior has been discussed, and various substances have been suggested for the purpose. Cellulose acetate, synthetic resins, fluosilicates, hard waxes and silicon ester have all been mentioned in this connection, as they would add somewhat to the strength of the beam by filling up the cavities and thus making it more solid.

Amongst the proprietary preparations that can be obtained for exterminating the beetle is the "Kenford Fluid," which is claimed to destroy both the beetle and the grub as well as the eggs. This fluid is an oily body, having a high flash point, which penetrates deeply into the wood, conveying a new patented chemical body to the interior, which, although non-poisonous to human beings and animals, is both a contact and stomach poison to all kinds of insects. The preparation also leaves a permanent deposit on the surface, so that any insects which attempt to enter or leave the wood are destroyed, and it contains a radio-active mineral compound which vaporises very slowly, penetrating to the farthest limits of the burrow system and destroying all forms of insect life which may have escaped contact with the fluid. It is also recommended as a remedy for dry rot.

The method of application is similar to that already described on p. 180, the liquid being either brushed or sprayed on to the surface of the timber. One gallon is calculated to cover from 10 to 20 square yards according to the condition of the wood and the extent of the damage it has sustained. The "Kenford Death-watch Beetle Fluid" was selected for use in the treatment of the infested timbers in Peterborough and Canterbury Cathedrals, and it has also been employed on many other notable buildings and residences in different parts of the country.

There are two types of the fluid : the " Standard " type, for all ordinary purposes, and the Formula " A " type, which is intended for use on fine finishes and on delicate old paint which it is desired to preserve, owing to their great sentimental or material value. A consolidating fluid is also supplied for use on timber that has been considerably weakened by the depredations of the grub ; this solution hardens within the burrows, thus binding the fibres together and strengthening the timber by consolidating it into a solid piece.

The cost of the Death-watch Beetle Fluid is from 5*s*. 6*d*. per pint up to 26*s*. 8*d*. per gallon for small quantities ; in bulk it is supplied at cheaper rates, varying from 23*s*. 4*d*. per gallon for two gallons down to 13*s*. 8*d*. per gallon for fifty gallons. A substantial discount is allowed to architects, builders, etc., off the latter prices.

There is one rather significant fact in connection with the very difficult problem of how to deal with the death-watch beetle, which deserves, and in fact has received, a good deal of attention. This is the comparative effect on the liability of the timber to be attacked, of a well-ventilated and well-lighted position as against one that is dark and has a stagnant atmosphere. It has often been observed that the timbers in church towers and belfries which are provided with a good circulation of air, in addition to a fair amount of natural illumination, rarely suffer any considerable damage from the beetle, and it would appear that these conditions are strongly inimical to its undisturbed operation.

A very good example of this can be seen in the Curfew Tower at Windsor Castle. One of the oldest portions of this celebrated fortress, the Curfew Tower is, at the same time, one of the most interesting. The interior contains a good deal of massive oak framing for the support of the floors and the peal of bells which are hung in the roof, and the timber is in such an excellent state of preservation as to constitute a particular feature of interest, owing to its great age. The Tower is well lighted by the numerous windows and loopholes which pierce the walls, and a good circulation of fresh air is also maintained from the same source. As a contrast to this, most of the old oak roofs which have suffered such extensive damage from the attentions of *Xestobium* have very little illumination, and the atmosphere is inevitably stagnant. The fact that such conditions nearly always exist in buildings which are infested on a large scale certainly lends colour to the view that a close relationship exists between the operations of the beetle and the absence of light and fresh air.

Sir Frank Baines has stated that in his opinion the question of ventilation is a most important one and cannot be too strongly emphasised. He also remarks that, on the advice of Professor Maxwell-Lefroy, he has much improved the ventilation in the roofs of certain structures which are dealt with by His Majesty's Office of Works.

This idea is accentuated by the fact that in most cases nearly all the chief points of attack are situated, or commence, in the darkest and least accessible portions of the building, such as the ends of beams and roof principals that are built into the wall, and at the junction between the various timbers. In this respect a very strong resemblance exists between the attack of the beetle and the development of dry rot, as the latter needs a badly ventilated situation or it will not thrive, and it is extremely apt to commence operations at the ends of timbers that are totally enclosed with masonry. Thus the practice of leaving an open space round the ends of the beams, as described and illustrated on p. 70, is an advantage from both points of view.

There is also another cause which appears to encourage the development of both beetle and dry rot in the same way as the absence of ventilation ; this is a certain amount of warmth. It can safely be assumed that most of the damage that is wrought by the larvæ is situated in the roof timbers of the building concerned, and that the floors and other woodwork suffer less frequently in this respect. This fact immediately suggests that the trouble is aggravated by a moderately high temperature, as the heat that is provided for warming the building naturally rises to the roof, and in the absence of ventilating shafts or outlets of one kind or other it is obliged to remain there, so that the air in the roof space is more or less permanently heated. Thus the three conditions of warmth, darkness and stagnation, which are necessary for the development of dry rot, also appear to be, if not essential factors in the life history of the insect, at least predisposing causes in any serious attack.

The influence that is exerted by extremes of temperature on the activity of the grub is common to most insect life. It was noted by the writer, who obtained several specimens of larvæ from the badly infected beam illustrated in Fig. 18. The beam, after being removed from its position, had been left standing in the open for several weeks, where it was exposed to the air during rather cold April weather, and the grubs, when extracted from their burrows, were almost lifeless and showed very little sign of movement. Very shortly after they were transferred to a warm atmosphere, however, the grubs began to stir, and within a few hours they were completely revived and travelled around as fast as their very limited abilities would permit, which goes to prove that, while a low temperature retards their work, their operations are assisted by some little warmth.

Spraying, then, is the only practicable method by which timber *in situ* can be treated with any hope of satisfactory results, but a certain amount of preparation must be carried out before the operation is commenced to ensure that the deepest possible penetration of the solution shall be obtained. The timbers will, no doubt, need a thorough cleaning down as a preliminary, all dust, dirt and cobwebs being removed from their surfaces, and as much of the excreta of the beetle as can be managed must be brushed or scraped out of the tunnels wherever they are accessible. The excreta is in the form of tiny bun-shaped pellets, and they will be mixed with a large proportion of wood dust. The removal of the dust and pellets can also be effected by the employment of compressed air, a stream of which, if directed on to the surface of the timber, will blow the dust out of the crevices. An alternative, and probably cheaper and more effective method still, is to extract the loose material by means of a vacuum apparatus ; this will cleanse the tunnels more effectively, and will avoid the distribution of clouds of dirt and dust, which would otherwise settle on the other timbers in the vicinity that have already been dealt with. The freeing of the tunnels is rather important, and if neglected it would result in a considerable obstacle to the penetration of both liquid and vapour, as after the timber has been consumed and digested it is evacuated by the grub as it works its way along, completely blocking the burrow in its rear. In many cases the tunnels are choked with dust, which is packed so tightly as to cause a good deal of difficulty in effecting its removal either by air blast or by vacuum. This can be overcome to some extent by striking the beam repeatedly with a hammer or mallet to loosen the dust, the extracting apparatus being kept working at full power meanwhile. Thus the particles will be drawn out of the burrows as soon as they are loosened. The surfaces of the timber should also be thoroughly cleansed where they are very dirty, or much of the effect of the spraying will be lost by the presence of a film of dirt and smoke which collects on the timber in the course of time.

The apparatus that was employed for spraying the roof of Westminster Hall consisted of a 10-gallon container, which was made of an acid-proof metal; the container was mounted on an iron framework having wheels, so that it could be moved about from place to place as required without difficulty. The apparatus was provided with a hand pump, capable of developing pressure up to 120 lbs. per square inch, the usual graduated pressure gauge being included to regulate the treatment and to prevent accidents. As a general rule, it was found that approximately 60 lbs. per square inch were sufficient to carry out the spraying, and this was the pressure at which it was normally worked. During the time that the tetrachlorethane mixture was employed it was found by the Home Office to be of such a poisonous nature, and to have such a deleterious effect on the men who were engaged in the spraying operations, that they were compelled to wear a special form of gas mask to prevent serious injury to their health. As already observed, however, this solution is not now recommended, the dichlorbenzene mixture mentioned on p. 182 having been proved equally effective, while being cheaper, simpler, and less dangerous.

The solution was sprayed liberally over every portion of the timbers both of the original roof and of the newer pieces that had been added during the repairs. Spraying was continued until the wood had absorbed the maximum amount of which it was capable, so that the liquid, being unable to soak in, streamed off the surface. Special nozzles had to be devised to spray the smaller parts of the carved work and tracery, and to get into the corners that could not be reached by the ordinary apparatus.

Considerable doubt exists as to the date at which the infection commenced in the more important structures that are now undergoing restoration. It has not yet been found possible to correctly estimate the date at which the beetles first obtain access to the building, as so far it is not known exactly how much ground is traversed by the larva during its life-cycle of three years. In addition to the doubt on this point, it is quite impossible to form any accurate estimate of the number of grubs that are concealed in the timber at a given moment, so that it is exceedingly difficult to form any theory on the subject of the length of time that has been taken in the destruction that has been committed. It is known that in some cases irreparable damage has been caused in a comparatively short space of time. Professor Lefroy gives an instance in which an oak floor that was put down in 1882 has already perished to such an extent as to be quite useless. It is probable that this is an isolated case, and that a much longer time has been occupied in most of the serious attacks that have been discovered during recent years ; floor timbers, too, would, as a rule, be of smaller sectional area than the immense beams in the roofs of the larger structures, and would thus be destroyed in a correspondingly shorter period. Some cases have been known where an attack has commenced a century or more ago and has ceased from some cause which is at present unknown.

Whether the attacks usually started at the time when the buildings were erected, owing to the use of infested wood, or shortly afterwards, or whether they were due to the introduction of beetles into timbers which had not received any protective treatment, it is not possible to say, but what little evidence is available and the deductions that can be made therefrom point directly to the fact that unprotected timber is always open to attack, and to the absolute necessity for some steps to be put into force which will constitute an effectual barrier to the insects for all time. This is, of course, looking a considerable way ahead, but it is imperatively necessary to take a long view of the subject if our historic buildings are to be preserved for the use and enjoyment of posterity, which is certainly desirable from all points of view.

So much has been heard of the beetle during recent years and so much apprehension has been caused in the minds of the owners of historic ancient buildings, or those who are responsible for their safe keeping, that it is now realised what a very wide field exists for scientific research into the most effective remedy by which the trouble can be cured. Serious investigations have therefore been commenced with the object of collecting reliable data that can be utilised to devise effective preventive measures. These will necessarily occupy some little time, for as the life-cycle of the beetle takes at least three, and possibly four, years for its completion, it is inevitable that some years must elapse before a comprehensive knowledge of its history and habits can be obtained and the details collated and studied.

The preservation of our national heirlooms in the shape of any historic structure is now undertaken by the Ancient Monuments Department of His Majesty's Office of Works, but there are many privately owned buildings which are of almost equal value and importance where the problem is quite as acute, and where a less watchful vigilance is exercised in the prevention of natural decay. In the past, restoration measures have been directed mainly to the masonry and the external features of the structures concerned, but the additional responsibility of the roofs and woodwork has now been recognised, and increased anxiety has been caused by the ravages of this ubiquitous pest.

Too much importance cannot be attached to the absolute necessity for the very greatest circumspection in the repair of timber roofs and floors, in order that infection may not be introduced into buildings that have hitherto been free from suspicion, and if suitable measures for the extermination of existing larvæ are put into operation simultaneously with the restoration work, a reasonable hope of the ultimate freedom of the buildings from the beetle and its grub can be entertained.

INDEX

ACETATE, cellulose, 188
Acid,
  carbolic, 75, 88, 132
  carbonic, 12
  hydrocyanic, 128, 129
  sulphuric, 125
Age of trees, 12
Air-bricks, 53, 54, 57, 58, 60, 62, 66, 68, 69, 94, 96, 98, 100
Air,
  circulation of, 57, 59, 66, 73, 79, 94, 98, 100
  current, velocity of, 59
  drain, 103
  flue, 67, 94
  fresh, 52, 151
  pit ventilation, 100
  pocket round beams, 70, 95, 192
  saturated, 64, 65
  shaft, 67, 94
  stagnant, 50, 151, 192
  supply for beetles, 125
Albumen, 117, 118, 144
  coagulation of, 75
Alburnum, 13
Alcohol for beetles, 124
Alkali, 29, 73
Ammonia, 131
Ancient Monuments Board, 169, 198
Annual rings, 10, 12, 15, 142
Anobiidæ, 136
Anobium punctatum, 115, 132, 139, 141, 144, 145, 146
Antiquarian Society, 185
Antiseptic treatment of timber, 75, 175
Ant, white, 7, 21, 109
Apparatus, spraying, 194
Ash, 9
Asphalte, 101
Attack of beetle, termination of, 150
Attack of insects, 7, 20, 109, 132, 150
Attrition, 5
Autumn-formed wood, 13

BACTERIA, soil, 22
Baines, Sir Frank, 156, 159, 160, 165, 166, 179, 191
Baird, Sir John, 158, 169
Bark, 9, 12, 13, 14
Barry, Sir Charles, 158, 163
Barium oleate, 181, 182, 183
Beam
  destroyed by beetle, 142
  to strengthen, 188
  to test for soundness, 172
Beech, 9, 147
Beetle,
  air supply of, 125
  and darkness, 151
  and warmth, 151
  common furniture, 107, 111, 115
  death-watch, 8, 22, 111, 135
    extermination of, 114, 151, 171, 174, 177, 179
  detection of, 185, 186
  dimensions of, 115, 146
  exit holes, 119, 121
  fumigation of, 126, 127, 128, 130, 177
  furniture, remedies for, 122, 126
  heat to kill, 126, 177
  in its burrow, 142
  jaws of, 140
  ovipositor, 116
  pairing of, 116, 138, 143, 146
  spines of, 118, 139, 141, 143
  tapping of, 121, 136, 137, 146
  temperature to kill, 127
Benzene, 131
  for furniture beetle, 124

Bichloride of mercury, 88, 124, 181
Bishop Fisher, 157
Bishops, seven, 157
Block floors, 71
Blue Book on Westminster Hall, 159, 163, 177, 179
Bond timbers, 71, 95
Breeze bricks, 98
  concrete, 72
Bricks, perforated, 70
Brimstone, 129, 130
Broad-leaved trees, 9
Broken gutters, 102
Building,
  disinfection of, 88
  plan of, 61
Byron, 157

CABOT'S Quilt, 73
California, discovery in, 20
Cambium, 12, 15
Camphor, 129
Canadian Forest Products Laboratory, 43
Candle, sulphur, 129
Canterbury Cathedral, 189
Capillary attraction, 63, 101, 102
Carbolic acid, 75, 88, 132
Carbolineum for beetles, 125
Carbon, 18
  dioxide, 39
  disulphide for beetles, 128
  tetrachloride for beetles, 124, 131
Carbonic acid, 12
Case-hardening of timber, 17
Cedarwood oil, 180, 183
Cells, 11, 14, 15, 35, 75, 78, 119
Cellular tissue, 10, 11, 12, 15
Cellulose, 17
  acetate, 188
Charles I., 157
Chestnut, 147
Chimney flues, 68
Chrysalis, 119, 146
Circulation of air, 57, 59, 66, 73, 79, 94, 96, 98, 100
CO_2, 12
Coagulation of albumen, 75
Commission, Science and Art Department, 131
Common furniture beetle, 107, 111, 115
Composition of timber, 18
Compressive strength of timber reduced, 43
Concentric rings, 10, 142
Concrete,
  breeze, 72
  gauge of, 90
  porous, 101
Concreted floors, 63, 66, 72, 87, 89
Condensation, 63, 64, 66
Coniferous trees, 10, 15, 109
Coniophora cerebella, 28, 31, 40, 47
Corbels, 96
Corrosive sublimate, 88, 124, 181
Cost of Kenford Fluid, 190
    of Peterborough Cathedral repairs, 185
    of treating beetles, 184
    of Westminster Hall repairs, 185
Cotton, silicate, 73
Creosote, 15, 72, 75, 132
Cromwell, 157
Curfew Tower at Windsor, 191

DAMPNESS, 27, 29, 31, 51, 62, 79, 101, 151
Damp ground, 62
Damp-proof courses, 63, 93, 101, 102
"Damp Walls," 93
Darkness and beetles, 151
  and dry rot, 51
Date of infestation, 148, 149
Death-watch beetle, 8, 22, 111, 135, 146, 176
    detection of, 185, 186
    dichlorbenzene, 180, 181, 182, 183, 195
    dimensions of, 146
    tetrachlorethane, 180
    to kill, Kenford Fluid, 189
      liquid, 179, 181, 182,
Decomposition, 5, 14, 17, 18, 19, 24

Deposition of eggs, 116, 122, 123, 138, 150
Designer of Westminster Hall roof, 156
Detection of beetle, 185, 186
Deutsche Tischler-Zeitung, 124
Development of dry rot, 35, 40, 51
Dew point, 65
Dichlorbenzene, 180, 181, 182, 183, 195
Dimensions
  of beetle, 115, 146
  of dry rot spores, 29
  of hammer-beams, 163
  of hammer-posts, 164
  of larva, 116, 140
Discovery in California, 20
Disinfection
  of building, 88, 180, 181, 184
  of timber, 175
  of tools, 97
Drain, air, 102
Dr. Gahan on the beetle, 120, 126, 127, 137, 138
Drying timber, temperature for, 79
Dry rot, 8, 25, 103, 192
  and condensation, 66
  and darkness, 51
  and freezing point, 31
  and moisture, 31, 38, 40, 50
  and ventilation, 50, 52
  and warmth, 50
  at Reading, 43
  cause of, 27
  development of, 35, 40, 51
  eradication of, 81
  fructification of, 38, 39, 40, 47, 86, 87
  germination of, 29, 30, 34, 37, 75, 79
  how it starts, 33
  infection, 30
  in Hampshire, 44
  in North Wales, 32
  in old buildings, 81, 83, 84, 87
  in stables, 45
  in Yorkshire, 83
  mould, 36
Dry rot—*cont.*
  mycelium of, 37, 39, 40, 47, 82, 87
  prevention of, 48
  remedies for, 81
  signs of, 41, 83
  size of spores, 29
  spread of, 43, 44, 86
  temperature, 30
  tests for, 41, 46
  treatment for, 35
  vitality of, 75
Duramen, 13

EARL OF STRAFFORD, 157
Eaves gutters, broken, 102
Edward VII., 157
Eggs, 111, 115, 116, 120, 123, 132, 139, 171, 181, 184
  deposition of, 116, 122, 123, 138, 150
Elm, 9, 15
Endogens, 9
Eradication of dry rot, 81
Eremacausis, 22
Evans' Wood-worm Killer, 126
Evaporation of moisture, 16, 64, 71, 73
Evergreen oak, 14
Excreta of grubs, 186, 193
Exit holes of beetle, 119, 121, 132, 173, 186
Exogens, 9
Expansion of heated matter, 55
Experiments in United States, 17
Extermination of death-watch beetle, 114, 151, 171, 174, 177, 179

FALCK on dry rot, 30
Fir, 10, 18, 76
Fires, forest, 6
Fisher, Bishop, 157
Floor boards, 73, 83, 98
Floors,
  concreted, 63, 66, 72, 87, 89
  solid, 98
Flower in oak, 14
Flue,
  air, 67, 94
  chimney, 68

Fluosilicates, 189
Force pump, 187
Forest fires, 6
Forest Products Laboratory, 43
Forest Service, United States, 20
Freezing point and dry rot, 31
Fresh air, 52, 151
Fructification of dry rot, 38, 39, 40, 47, 86, 87
Fumigation to kill beetles, 126, 127, 128, 130, 177
Fungi, 22, 28, 37, 42, 46
Furniture beetle, 107, 111, 115
  dimensions of, 115
  remedies for, 122
  to kill,
    alcohol, 124, 131
    ammonia, 131
    benzene, 124, 131
    carbolineum, 125
    carbon disulphide, 128
    carbon tetrachloride, 124, 131
    fumigation, 126, 127, 128, 130, 177
    heat, 126
    hydrocyanic gas, 128, 129
    lime sulphate, 125
    mercurial paste, 124
    mercuric chloride, 131
    naphthalene, 124
    paraffin, 122, 123, 124, 180
    petrol, 124
    soap lye, 125
    sulphur dioxide, 129
    sulphuric acid, 125
    temperature, 127
    turpentine, 124
    vinegar, 124
Furniture, worm-eaten, 113, 121

GAHAN, Dr., on beetles, 120, 126, 127, 137, 138
Gassing to exterminate beetles, 126, 127, 128
Gauge of concrete, 190
Germination of dry rot spores, 29, 30, 34, 37, 75, 79
Gordon, Lord George, 157
Government Blue Book on Westminster Hall, 159, 163, 177, 179
Gravitation, 55
Ground damp, 62
Growth of timber, 10, 12
Grubs, 111, 116, 117, 119, 125, 131, 132, 138, 139, 140, 142, 143, 145, 149, 161, 175, 178, 181, 183, 193
  excreta of, 186, 193
Gutters, broken, 102

HAMMER-BEAM, 162, 163, 165, 186
Hammer-post, 162, 163, 164
Hampshire, dry rot in, 44
Hardwoods, 9, 14, 15, 35, 109, 173
Hastings, Warren, 157
Heartwood, 13, 14, 22, 96, 114
Heat,
  expansion by, 55
  to kill beetles, 126, 177
Herland, Hugh, 156
History of Westminster Hall, 154
Holes, exit, 119, 121, 132, 173, 186
H.M. Office of Works, 156, 166, 169, 170, 179, 191, 198
Honeycombed walls, 58, 62, 94, 97
Hugh Herland, 156
Hydrocyanic gas for beetles, 128, 129
Hydrogen, 18
Hyphæ, 34, 35, 38, 42, 44, 47, 75, 76, 85, 86, 87, 89, 95, 97, 104

ILLUMINATION against beetles, 151, 190
Impregnating timber, 17, 178, 188
Improved method of inserting air-brick, 60
Indications of dry rot, 41, 83
Infection by dry rot, 30
Infestation, date of, 148, 149

Influence of temperature on grubs, 193
Inorganic portion of wood, 16
Insect attacks, 7, 20, 109, 132, 150
Insects, wood-boring, 7, 109, 110
Integral waterproofers, 92
Inward-growing trees, 9
Iron wall plates, 71, 95
Ivy roots resemble dry rot, 46

Jarrah, 9
Jaws of beetle, 140
Joists must be removed, 86

Kenford Beetle Fluid, 189
Killer, Evans' Wood-worm, 126
King's Speech, the, 169

Larch, 15
Larva, 111, 116, 117, 119, 125, 131, 132, 138, 139, 140, 142, 143, 145, 149, 161, 175, 178, 181, 183, 193
  dimensions of, 116, 140
  unable to crawl, 142
Laud, Archbishop, 157
Lead, 16
Lefroy, Professor Maxwell- 115, 144, 145, 147, 174, 179, 191, 196
Leibig, Baron Von, 22
Life-cycle of death-watch beetle, 136, 144, 196
Life-cycle of furniture beetle, 116, 119, 120
Lignin, 17, 28, 35
Lime sulphate for beetles, 125
Linoleum on floors, 74
Liquid ammonia, 131
  to kill beetles, 179
Lord George Gordon, 157

Mahogany, 9
Materials, unsuitable, 5
Maturity of trees, 15
Maxwell-Lefroy, Professor, 115, 144, 145, 147, 174, 179, 191, 196
Medullary rays, 12, 13, 14
  sheath, 11
Mercurial paste, 124
Mercury, bichloride of, 88, 124, 181
Merulius lachrymans, 28, 31, 34, 35, 38, 39, 40, 42, 43, 45, 47, 82
Methyl alcohol, 124, 131
Methylated spirits, 124, 131
Mica flap ventilator, 67, 68
Mineral oil, 182, 183
Moisture and dry rot, 31, 38, 40, 50
Moisture, evaporation of, 16, 64, 71, 73
Molasses as a preservative, 76
Mould, dry rot, 36
Mycelium of dry rot, 37, 39, 40, 47, 82, 87

Naphthalene for furniture beetle, 124
Needle-leaved trees, 9
New wood, 9
North Wales, dry rot in, 32

Oak, 9, 14, 15, 19, 44, 77, 108, 147, 161, 186
  evergreen, 14
  from Wadhurst Forest, 168
  quartered, 14
  stripping, 15, 77
Observer, extract from, 158
Oil,
  cedarwood, 180, 183
  mineral, 182, 183
Old buildings, dry rot in, 81, 83, 84, 87
Oleate, barium, 181, 182, 183
Organic portion of wood, 16, 17
Outward-growing trees, 9
Ovipositor of beetle, 116
Oxidation, 28
Oxygen, 18

Paint, 16
Pairing of beetle, 116, 138, 143, 146
Paraffin for furniture beetle, 122, 123, 180

Paraffin wax, 180, 181, 183
Parasites, 20, 28, 109
Parchment size, 132
Partition walls, 58
Penetration of solution, 179, 188
Perforated bricks, 70
Peterborough Cathedral, 185, 189
Petrol for furniture beetle, 124
Phenol, 75, 88, 132
Pine, 10, 147
Pitch, 101
Pith, 10, 11, 13, 14
Plan of building, 61
Plates, wall, 71, 95
Pocket, air, round beams, 70, 95, 192
Poison solutions, 180, 181, 182
Polyporus vaporarius, 28, 32, 34, 40, 78
Poplar, 15.
Porous concrete, 101
Powell Wood-Process, 76
Preservation of timber, 17, 77
Preservative,
  molasses as a, 76
  treatment of timber, 75, 96
Prevention of dry rot, 48
Principal rafters, 163, 185, 192
Professor Maxwell-Lefroy, 115, 144, 145, 147, 174, 179, 191, 196
Pugging, 73
Pump, force, 187
Pupa, 112, 119, 125, 138, 145, 175, 183

QUALIFICATIONS of solution, 179
Quartered oak, 14
Quilt, Cabot's, 73
Quotation from *Observer*, 158

RAFTERS, principal, 163, 185, 192
Rays, medullary, 12, 13, 14
Reading, dry rot at, 43
Reinforcement, steel, 166, 167
Remedies for dry rot, 81
Remedies for furniture beetle, 122, 126
Resin, synthetic, 189
Restoration of Westminster Hall, 169
Richard II., 155
Rings,
  annual, 10, 12, 15
  concentric, 10
Roots of ivy resemble dry rot, 46
Rot, dry, 8, 25, 103, 192
  wet, 28
Rufus, William, 155, 159

SAP, 10, 11, 12, 13, 14, 18, 77
Sapwood, 13, 14, 18, 22, 76, 78, 96, 114, 142
Saturated air, 64, 65
Scheme for repairing the roof, 165
Science and Art Department Commission, 131
"Seasoning of Timber," 17, 77
Seven bishops, 157
Shaft, air, 67, 94
Sheath, medullary, 11
Ship worm, 7, 21
Signs of dry rot, 41, 83
Silicate cotton, 73
Silicon ester, 189
Sir Charles Barry, 158, 163
Sir Frank Baines, 156, 159, 160, 165, 166, 179, 191
Sir John Baird, 158, 169
Site, concreted, 63, 66, 72, 87, 89
Size, parchment, 132
Sleepers, 7, 86, 97, 101, 110
Soap lye for beetles, 125
  solvent, 180, 181, 183
Society of Antiquaries, 185
Softwoods, 10, 14, 35, 78, 186
Soil bacteria, 22
Solid floors, 98
Solution,
  penetration of, 179, 188
  qualifications of, 179
  to kill beetles, 179, 180, 182
South Kensington Museum, 131

Spines of grub, 118, 139, 141, 143
Splitting, 17
Spores, dry rot,
  development of, 35
  dimensions of, 29
  germination of, 29, 30, 34, 37, 75, 79
Spraying apparatus, 194
  disinfectant, 88, 180, 181, 184, 188, 193
Spread of dry rot, 43, 44, 86
Stables, dry rot in, 45
Stagnant air, 50, 151, 192
Steel reinforcement, 166, 167
  trusses, 168, 169
Stevenson, William, 114
St. George's Chapel, 138, 142
Strafford, Earl of, 157
Strengthen beam, to, 188
Strength of timber reduced, 43
Stripping oak, 15, 77
Sulphur candle, 129
  dioxide for beetles, 129
Sulphuric acid for beetles, 125
Synthetic resin, 189

TANNING, 15
Tapping of beetle, 121, 136, 137, 146
Tarring, 6, 16, 72, 101
Teak, 9
Temperature
  for drying timber, 79
  for dry rot, 30, 192
  of air in ventilation, 59
  to kill beetles, 127
Teredo navalis, 7, 21, 171
Termination of beetle's attack, 151
Tests
  for dry rot, 41, 46
  for soundness, 172
Tetrachlorethane, 180
Timber, 3, 9, 108
  a million years old, 20
  antiseptic treatment of, 75, 175
  composition of, 18
  compressive strength reduced, 43
Timber—*cont.*
  condition of, attacked by dry rot, 42
  damaged by heat, 177
  growth of, 10, 12
  preservative, 75, 96
  "Seasoning and Preservation of," 17, 77
  temperature for drying, 79, 177
  unseasoned, 33, 51, 69, 77, 96, 168
  waste of, 5
Timbers, bond, 71, 95
Tissue, cellular, 10, 11, 12, 15
Tobin's tube, 100
Tools, disinfection of, 97
Trees, 9
  age of, 12
  maturity of, 15
Trichlorethylene, 180
Trusses, steel, 168, 169
Turpentine for furniture beetle, 124

UNSEASONED timber, 33, 51, 69, 77, 96, 168
Unsuitable materials, 5
U.S.A. experiments, 17
U.S.A. Forest Service, 20

VACUUM cleaning, 194
Vapour to exterminate beetles, 126, 127, 128, 179, 182
Velocity of air current, 59
Ventilation, 18, 44, 50, 52, 54, 61, 151, 190, 192
  by air pit, 100
  mechanical, 55
  natural, 55, 56
  of solid floors, 98
  temperature of air, 59
Ventilator, mica flap, 67, 68
Vinegar for furniture beetle, 124
Vitality of dry rot, 75

WADHURST Forest, 168
Wall plates, 71, 95
"Walls, Damp," 93

Walls,
  honeycombed, 58, 62, 95, 97
  partition, 58
Walnut, 9, 113
Warmth and beetles, 151
  and dry rot, 50
Warping, 17
Warren Hastings, 157
Waste, 3
Waterproofed mortar, 92, 101
Waterproofers, integral, 92
Wax, 189
  paraffin, 180, 181, 183
Westminster Hall, 154
  restoration, 169
  roof, 19, 135, 152, 159, 170, 173, 176
    designer of, 156
    height of, 160
    repair of, 152, 158, 165
Westwood on the grub, 146
Wet rot, 28
White ant, 7, 21, 109
William Rufus, 155, 159
William Stevenson, 114
Willow, 147
Windsor Castle, 191
Wood,
  autumn-formed, 13
  block floors, 71
  boring insects, 7, 109, 110
  heart, 13
  new, 9
  Process, Powell, 76
  sap, 13, 14, 18
  worm, 111
Wood-worm Killer, Evans', 126
Worm-eaten furniture, 111, 121
  worm, ship, 7, 21

Xestobium rufovillosum, 136
  tessellatum, 136, 139, 140, 144, 152, 161, 191

YEAST, 144
Yorkshire, dry rot in, 83

ZINC, 16, 181

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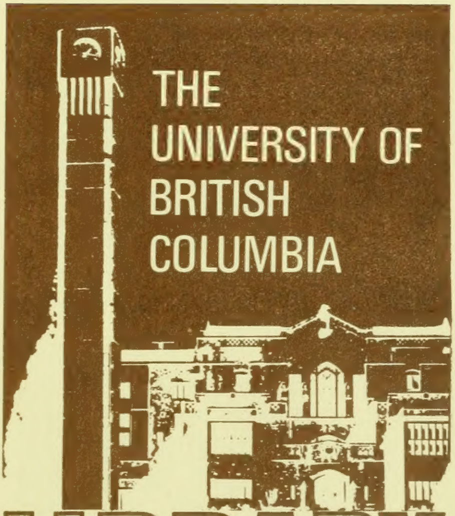

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